

PRELIMINARY REVIEW DRAFT

CHAPTER 2. PROBLEM STATEMENT

2.1 Introduction

In the Klamath River in California increased water temperatures, elevated nutrient levels, low dissolved oxygen concentrations, elevated pH, potential ammonia toxicity, increased incidence of fish disease, an abundance of aquatic plant growth - high Chlorophyll-*a* levels (both planktonic and periphytic algae), and high concentrations of potentially toxigenic blue-green algae, particularly in the impounded reaches, decrease the quality and quantity of suitable habitat for fish and aquatic life, and have disrupted traditional cultural uses of the river by resident Tribes. These conditions contribute to the non-attainment of beneficial uses, including the most sensitive beneficial uses: those associated with the cold water fishery (specifically the salmonid fishery) in California, and those related to cultural uses and practices.

The purpose of the Klamath River basin TMDL problem statement is to:

- Provide an overarching assessment framework for the TMDL;
- Present a summary assessment of current water quality conditions; and
- Document beneficial use impairment.

The Klamath River numeric and narrative water quality objectives and beneficial uses that are the comparative benchmarks for the problem statement assessment are described in the California Regional Water Board's *Water Quality Control Plan for the North Coast Region* (Basin Plan). Section 2.2 of the problem statement, Water Quality Standards, consists of a summary description of the Basin Plan and Tribal water quality standards, objectives, and beneficial uses addressed in the TMDL. The Basin Plan and Tribal water quality standards provide the regulatory context for the assessment that follows.

Section 2.3 Water Quality Conceptual Models Overview, describes the technical approach used in the problem statement assessment. To ensure a comprehensive assessment and decision framework, the California Regional Water Board has adopted the technical approach from the California Nutrient Numeric Endpoints (CA NNE) framework (Tetra Tech 2006). The CA NNE is used to assess and describe the water quality impacts associated with nutrient and organic enrichment and temperature alteration. The approach involves the development of conceptual models that illustrate how key factors and processes link the primary stressors (nutrients and organic enrichment, and altered temperature regime) with impacts on beneficial uses. In addition, the conceptual models can be used to identify key uncertainties and data gaps, provide lines of evidence for numeric targets and allocations, and are useful tools for adaptive management. The conceptual models for the Klamath River focus on water quality related impacts but also provide perspective on other factors that are also contributing to impairment of beneficial uses within the Klamath River basin.

Section 2.4 Evidence of Water Quality Objective Exceedances, as the title suggests, presents evidence of exceedances of water quality objectives. The California Regional

PRELIMINARY REVIEW DRAFT

Water Board has compiled water quality monitoring data from several sources to support this analysis (e.g., dissolved oxygen, temperature, pH, nutrient enrichment) and CA NNE indicators (e.g., benthic algal biomass, chlorophyll a, diurnal DO and pH patterns). The purpose of the analysis of water quality objectives and CA NNE indicators is to evaluate the risk of impairment to beneficial uses. The Section 2.4 analysis uses data from eleven stations along the length of the Klamath River from the Oregon border to its mouth at the Pacific Ocean.

As detailed in Section 2.5 Evidence of Beneficial Use Impairment, many designated beneficial uses are not being supported in the Klamath River. The purpose of Section 2.5 is to describe how poor water quality conditions are impairing beneficial uses in the Klamath River. The focus is on the status of the elements that are essential to each beneficial use. For example, to evaluate the Cold Freshwater Habitat (COLD) beneficial use, the historical and current status of the cold-water fishery is compared to demonstrate a significant degradation of fishery related beneficial uses.

Section 2.6 Problem Statement Synthesis, presents the problem statement conclusions regarding the status of Klamath River beneficial uses and the necessity for fully implementing the TMDL in a timely manner. The problem statement conclusions provide the focus for the TMDL pollutant allocations and implementation.

It is important to recognize that in the Klamath River basin there are factors that affect the condition of beneficial uses that are not directly addressed through the TMDL process. For the COLD beneficial use, a few of these factors include, but are not limited to:

- The presence of dams which impede passage of anadromous fish;
- Altered flow conditions that affect habitat conditions;
- The presence of hatchery raised fish with the potential for disease and genetic effects;
- Ocean and in-river fisheries harvest rates; and
- Global climate change.

This TMDL will not directly address these other non-TMDL pollutant related factors.

The problem statement description is a required component of any TMDL, but in this case it takes on added importance because of other ongoing regulatory processes within the Klamath Basin that must be kept clearly distinct from the TMDL process. The other ongoing regulatory processes include:

- The 50-year Federal Energy Regulatory Commission (FERC) relicense for the five dams included in the Klamath Hydroelectric Project; and
- Endangered Species Act (ESA) consultation for several native species that have special federal and or state status, including but not limited to Coho salmon, Shortnose sucker, and Bull trout.
- Tribal Trust responsibilities of the USEPA to Tribes and individual Indians.

PRELIMINARY REVIEW DRAFT

The mention of these other non-TMDL factors affecting water quality and other ongoing regulatory processes that will address some of these factors is meant to underscore the need for a comprehensive solution to restore ecosystem integrity to the Klamath River basin. The TMDL process described in this document is only one component of a restoration and management program that must be implemented in the next few years to preserve Klamath River water resource related uses in an acceptable manner.

2.2 Water Quality Standards

The USEPA describes a water quality standard as consisting of four basic elements: 1) designated uses of the water body, 2) water quality criteria to protect designated uses, 3) an antidegradation policy to maintain and protect existing uses and high quality waters, and 4) general policies addressing implementation issues. More information is available at <http://www.epa.gov/waterscience/standards/about/>.

The Porter Cologne Water Quality Control Act (Porter Cologne)⁴ modifies USEPA's language to refer to designated uses as "beneficial uses" and water quality criteria as "water quality objectives", which includes the state anti-degradation policy (Resolution 68-16). Porter Cologne also requires a "program of implementation" (Water Code section 13050(i)) for water quality protection in California. A "program of implementation" includes actions necessary to achieve objectives, a time schedule for the actions to be taken, and surveillance to determine compliance with objectives (see Water Code section 13242).

The California Regional Water Board has adopted the *Water Quality Control Plan for the North Coast Region* (Basin Plan) in which it establishes the region's water quality standards, including the standards that apply to that portion of the Klamath River basin that falls under the jurisdiction of the state of California. The Basin Plan has been approved by the California State Water Board and by USEPA and is in full force and effect.

Similarly, the Hoopa Valley Tribe has adopted the *Water Quality Control Plan for the Hoopa Valley Indian Reservation* that has been approved by USEPA and is in full effect. The Hoopa's standards apply to those portions of the Trinity and Klamath Rivers under the jurisdiction of the Hoopa Valley Tribe⁵.

The Yurok and Karuk Tribes have also adopted water quality standards, as has the Resighini Rancheria. These water quality plans and standards have not yet been approved by USEPA, however, and the California Regional Water Board will consider their content and use for guidance, as appropriate.

⁴ The Porter-Cologne Water Quality Control Act (Water Code §§ 13000 et seq.) is the act governing the water quality protection activities of the State Water Resources Control Board (State Board) and the nine regional boards within the state of California.

⁵ The Hoopa Valley Tribe owns land, 12 miles by 12 miles, primarily in the Trinity River watershed but intersecting with the Klamath River at Saints Rest Bar upstream of the confluence with the Trinity (www.hoopa-nsn.gov).

PRELIMINARY REVIEW DRAFT

The Quartz Valley Tribe, located along the Scott River, is in the process of developing a document on water quality standards for approval by its Tribal government.

2.2.1 Water Quality Control Plan for the North Coast Region

The Basin Plan (NCRWQCB 2007) is divided into 6 chapters. Of concern to this discussion are Chapter 2 (Beneficial Uses), Chapter 3 (Water Quality Objectives), Chapter 4 (Implementation Plans), and Chapter 5 (Plans and Policies).

2.2.1.1 Beneficial Uses

Chapter 2 of the Basin Plan identifies 28 beneficial uses of water within the North Coast region. Within the Klamath River basin, the following beneficial uses are identified as existing uses:

- MUN—Municipal and domestic supply
- AGR—Agricultural supply
- IND—Industrial service supply
- PRO—Industrial process supply
- GWR—Groundwater recharge
- FRSH—Freshwater replenishment
- NAV—Navigation
- POW—Hydropower generation
- REC1—Water contact recreation
- REC2—Non-contact water recreation
- COMM—Commercial and sport fishing
- WARM—Warm freshwater habitat
- COLD—Cold freshwater habitat
- WILD—Wildlife habitat
- RARE—Rare, threatened, or endangered species
- MAR—Marine habitat
- MIGR—Migration of aquatic organisms
- SPWN—Spawning, reproduction, and/or early development
- SHELL—Shellfish harvesting
- EST—Estuarine habitat
- AQUA-- Aquaculture
- CUL—Native American Culture

Of particular importance are those uses that are currently not fully supported due to degraded water quality. As detailed in Section 2.5, the Klamath River beneficial uses that are impaired include: COLD, RARE, MIGR, SPWN, CUL, COMM, REC1, REC2, and MUN. Subsistence fishing (FISH) is also listed in the Basin Plan as a beneficial use of the waters in the region. Although, the specific areas in which this use exists has not yet been designated in the Basin Plan, this does not alter the need to protect this existing beneficial use.

2.2.1.2 Water Quality Objectives

Chapter 3 of the Basin Plan identifies the water quality objectives deemed necessary to protect beneficial uses. Of concern to this TMDL are the water quality objectives concerning temperature, dissolved oxygen and nutrients. These are the parameters for which instream water quality data indicate exceedances and for which the Klamath River is listed on the 303(d) list as impaired⁶. Additionally, pH is discussed as it influences nutrient related parameters such as ammonia toxicity. Toxicity is also discussed as

⁶ The Klamath River downstream of the Trinity River is also on the 303(d) list for Sedimentation/Siltation, and Copco and Iron Gate Reservoirs are on the 303(d) list for Microcystin toxin.

PRELIMINARY REVIEW DRAFT

nutrient and temperature impairment contributes to the presence of blue-green algae blooms and associated presence of algal toxins.

Temperature

The Basin Plan contains two separate water quality objectives for temperature. The first objective is the intrastate temperature objective. This objective applies to all waters of the state.

The intrastate temperature objective is a narrative objective and reads:

The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such alteration in temperature does not adversely affect beneficial uses.

At no time or place shall the temperature of any COLD water be increased by more than 5°F above natural receiving water temperature.

At no time or place shall the temperature of WARM intrastate waters be increased more than 5°F above natural receiving water temperatures.

The second water quality objective for temperature is the interstate temperature objective contained in the state wide *Water Quality Control Plan for Control of Temperature In the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California* (Thermal Plan). The Thermal Plan, as adopted by the California State Water Board, is incorporated by reference in the Basin Plan (see Appendix 3 of the Basin Plan). The plan designates the Klamath River as a “Cold Interstate Water”. The “Cold Interstate Waters” objective is as follows:

Elevated temperature waste discharges into cold interstate waters are prohibited.

“Elevated Temperature Waste” is defined as:

Liquid, solid, or gaseous material including thermal waste discharged at a temperature higher than the natural temperature of receiving water. Irrigation return water is not considered elevated temperature waste for the purpose of this plan.

The interstate objective applies to waters that cross or define the state border. The interstate temperature objective augments, but does not supersede, the intrastate temperature objective.

The federal Clean Water Act (CWA) imposes a criterion for setting loads in addition to the water quality standards defined by the State. For waters impaired by temperature, CWA section 303(d)(1)(D) requires that states estimate “the total maximum daily thermal

PRELIMINARY REVIEW DRAFT

load required to assure protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife.”

Dissolved Oxygen

The existing dissolved oxygen (DO) objective is a set of numeric objectives that establish both an instantaneous minimum concentration of dissolved oxygen necessary in the water column and a mean value. The numeric objectives are assigned: 1) upstream of the Iron Gate Dam, 2) downstream of Iron Gate Dam, 3) on tributaries of the Middle Klamath River, and 4) on tributaries of the Lower Klamath River. The Klamath River DO impairment applies only to the mainstem.

Upstream of the Iron Gate Dam, the instantaneous minimum concentration of DO required is 7.0 mg/L. Half of the monthly mean DO values for the year must be 10.0 mg/L or greater.

Downstream of the Iron Gate Dam, the instantaneous minimum concentration of DO required is 8.0 mg/L. Half of the monthly mean DO values for the year must also be 10.0 mg/L or greater.

These DO objectives are the existing water quality objectives as currently contained in the Basin Plan. However, California Regional Water Board staff are currently developing a proposed revision to the DO objectives to better account for updates in the scientific literature regarding the DO requirements of cold water fishes, particularly salmonids. In addition, the proposed revision is intended to better account for the fact that basins with naturally high temperatures and nutrient levels have a limited capability for the water column to absorb oxygen, and may not always meet the existing minimum DO requirements.

It is staffs’ intent to revise the DO objectives prior to the California Regional Water Boards consideration of the Klamath River TMDLs. Staff will propose that the DO water quality objectives be revised by adding to the existing numeric objectives; for the protection of COLD a 7-day average of the daily mean⁷ of 8.0 mg/L DO in the water column; and replacing the existing numeric objective for SPWN with a 7-day average of the daily mean of 11.0 mg/L DO in the water column and 8.0 mg/L DO intergravel, to be applied during embryo and larval stages. These criteria are derived from the USEPA 1986 guidance.

In those waterbodies identified as COLD but unable to meet the salmonid life cycle requirements due to natural conditions, a minimum 85% saturation limit, as calculated based on natural water temperatures, will be proposed. Additionally, the proposed revision will state that in no case will the DO fall below 6.0 mg/L as an instantaneous minimum.

Nutrients

The nutrient objective is a narrative objective for controlling biostimulatory substances. Biostimulatory substances include nitrogen and phosphorus. The objective reads:

⁷ The daily mean is calculated from equally spaced values collected over a 24 hour period and including the day's minimum and maximum DO values. The 7-day average is applied as a moving average.

PRELIMINARY REVIEW DRAFT

Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.

Nutrient-Related Water Quality Objectives

The cycling of nutrients in an aquatic environment is strongly influenced by several factors. Depending on these factors, there is the potential for impacts to beneficial uses from secondary indicators of biostimulation such as algal biomass, chlorophyll a, DO, and pH.

The Basin Plan does not contain water quality objectives for algal biomass or chlorophyll a. The Basin Plan does contain a set of numeric objectives for pH in the Klamath River. Minimum pH levels shall not drop below 7.0 and maximum pH shall not be raised above 8.5.

Other impacts closely related to excessive nutrient inputs but qualitatively different are ammonia toxicity and microcystin⁸ toxicity. The Basin Plan does not include objectives for ammonia toxicity or microcystin.

The Basin Plan includes a narrative objective for toxicity that reads:

All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life.

2.2.1.3 Antidegradation Policies

There are two applicable antidegradation policies pertinent to water quality in the North Coast Region – a state policy and a federal policy. The state antidegradation policy is titled the *Statement of Policy with Respect to Maintaining High Quality Waters in California* and is commonly known as “Resolution 68-16.” The federal antidegradation policy is found at 40 CFR section 131.12. Both policies are incorporated in the Basin Plan for the North Coast Region. Although there are some differences in the state and federal policies, both require that whenever surface waters are of higher quality than necessary to protect the designated beneficial uses, such existing quality shall be maintained unless otherwise provided by the policies.

The state antidegradation policy applies to groundwater and surface water whose quality meets or exceeds water quality objectives, which may limit its direct applicability in impaired waterbodies. The state policy establishes a two-step process to determine if discharges that will degrade water quality are allowed. The federal antidegradation policy applies to surface waters that do not meet the applicable water quality objectives (i.e., impaired waters). Under the federal policy, an activity or discharge would be prohibited if the activity will lower the quality of surface water that does not meet water quality standards (i.e., the water quality is not sufficient to support designated beneficial uses) with limited exceptions set forth in federal regulations.

⁸ Microcystin is a toxin produced by a species of blue-green algae.

PRELIMINARY REVIEW DRAFT

2.2.1.4 Program of Implementation

Chapter 4 of the Basin Plan describes the program of implementation by which the beneficial uses and water quality objectives are applied and enforced. This chapter includes all the prohibitions, schedules of compliance, action plans, policies, and guidelines adopted by the California Regional Water Board for that purpose.

Chapter 6 of this TMDL staff report describes the proposed Implementation Plan for the TMDL, and will serve as the basis for the Action Plan for the Klamath River TMDL to be considered by the California Regional Water Board as an amendment to Chapter 4 of the Basin Plan.

2.2.2 ***Tribal Water Quality Standards***

The four Tribes in California with land along the mainstem Klamath River are the Hoopa Valley Tribe, the Karuk Tribe, the Resighini Rancheria, and the Yurok Tribe. As stated earlier, only the Hoopa Valley Tribe's water quality standards have been approved by the USEPA. The water quality standards developed by the Yurok and Karuk Tribes and Resighini Rancheria will be used as guidance in developing the TMDL as appropriate.

2.2.2.1 Hoopa Valley Tribe Beneficial Uses

The *Water Quality Control Plan for the Hoopa Valley Indian Reservation* (Hoopa Valley Tribal Environmental Protection Agency [HVTEPA] 2008) identifies nine existing, four potential, and one historical beneficial uses of water within their jurisdictional reach of the Klamath River. Figure 1.2 identifies the location and boundaries of the Hoopa Valley Indian Reservation, as well as the Yurok Indian Reservation.

- AGR—Agricultural supply(P)
- COLD—Cold freshwater habitat(E)
- CUL—Ceremonial and Cultural Water Use(H)
- GWR—Groundwater recharge(E)
- IND—Industrial service supply(P)
- MGR—Fish Migration(E)
- MUN—Municipal and domestic supply(P)
- PROC—Industrial process supply(P)
- REC1—Water contact recreation(E)
- REC2—Non-contact water recreation(E)
- SPWN—Spawning, reproduction, and/or early development(E)
- T&E—Preservation of Threatened(E)
- W&S—Wild and Scenic(E)
- WILD—Wildlife habitat and Endangered Species(E)

2.2.2.2 Hoopa Valley Tribe Water Quality Criteria

The Hoopa Valley Tribe has established DO and nutrients criteria for the Klamath River as described below. The Tribe has not developed temperature criteria for the Klamath River.

Dissolved Oxygen

The dissolved oxygen (DO) criteria consists of 7-day moving averages of the daily minimum DO concentrations.

In areas of the Klamath River designated as COLD (year-round), the 7-day moving average of the daily minimum DO concentration required in the water column must be

PRELIMINARY REVIEW DRAFT

8.0 mg/L or greater. Areas of the Klamath River designated as SPWN (whenever spawning occurs, has occurred in the past or has potential to occur) must have a 7-day moving average of the daily minimum DO concentration in the water column of the Klamath River of 11.0 mg/L or greater. The inter-gravel 7-day moving average of the daily minimum DO concentration required in the Klamath River areas designated as SPWN (whenever spawning occurs, has occurred in the past or has potential to occur) must be 8.0 mg/L or greater. In the event that these 7-day moving averages of the daily minimum DO standards “are not achievable due to natural conditions, then the COLD and SPAWN standard shall instead be DO concentrations equivalent to 90% saturation under natural receiving water temperatures.”

Nutrients

Nutrient criteria consist of several narrative criteria for controlling biostimulatory substances, nitrate and nitrite levels, and phosphate levels. Additionally, there are numeric objectives for nitrate, total nitrogen, ammonia, and total phosphorus.

The narrative criteria for biostimulatory substances reads:

Waters shall not contain bio-stimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.

The narrative criteria for nitrates applies to all waterbodies except those designated as municipal or domestic supply (which have their own numeric criteria) and reads:

...levels of nitrite shall not be increased by human related activity above the levels consistent with preservation of the specified beneficial uses.

The narrative criteria for nitrites reads:

Levels of nitrites shall not be increased, in any body of water, by human related activity above the levels consistent with preservation of the specified beneficial use corresponding to that water body.

The narrative criteria for phosphates reads:

In order to preserve the existing quality of water within the reservation boundaries from existing and to avoid potential eutrophication of phosphorous in any water body shall not be increased by human related activity above levels consistent with preservation of the specified beneficial uses. <sic>

Numeric nutrient criteria for the Klamath River are displayed below in Table 2.1. “If total nitrogen and total phosphorus standards are not achievable due to natural conditions, then the standards shall instead be the natural conditions for total nitrogen and total phosphorus (HVTEPA 2008).” As stated in a footnote within the Hoopa’s

PRELIMINARY REVIEW DRAFT

Basin Plan, these natural conditions are to be defined through consultation on the Klamath River TMDL.

Table 2.1: Hoopa Valley Tribe Numeric Nutrient Criteria

	Nitrate (mg/L)	Total N (mg/L) ¹	Ammonia (mgN/L)	Total P (mg/L) ¹
All Streams	-	0.2	- ²	0.035
Domestic/Municipal supply	10	-	-	-

Source: HVTEPA 2008

¹ 30-day mean of at least two samples per 30-day period.

² Maximum one-hour and 30-day average concentrations linked to pH by a formula. Formula can be found in HVTEPA 2008.

Nutrient-Related Water Quality Criteria

In addition to the above narrative and numeric criteria for nutrients, the *Water Quality Control Plan for the Hoopa Valley Indian Reservation* contains narrative criteria for toxicity and Cyanobacterial scums, as well as numeric criteria for parameters which are closely related to excessive nutrient inputs and influence toxicity.

The toxicity narrative reads:

All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal or aquatic life.

The Cyanobacterial scums narrative reads:

There shall be no presence of cyanobacterial scums.

Table 2.2 displays numeric criteria for algal biomass, pH, blue-green algae, and Microcystin.

Table 2.2: Hoopa Valley Tribe Numeric Nutrient and Toxicity Related Criteria

	Periphyton	Hydrogen Ion (pH)		Total Potentially Toxinogenic BGA Species ¹	<i>Microcystis aeruginosa</i> and Microcystin			
	Max annual periphyton mg chl-a per m ²	Max	Min	Recreation Water	Drinking Water		Recreation Water	
				cells/mL	cells/mL	Microcystin (ug/L)	cells/mL	Microcystin (ug/L)
All Streams	150	8.5	7.0	<100,000	<5000	<1	<40,000	<8

Source: HVTEPA 2008

¹ Includes: *Anabaena*, *Microcystis*, *Planktothrix*, *Nostoc*, *Coelosphaerium*, *Anabaenopsis*, *Aphanizomenon*, *Gloeotrichia*, and *Oscillatoria*.

2.2.2.3 Karuk Tribe, Resighini Rancheria, and Yurok Tribe Beneficial Uses

The Karuk Tribe⁹, Resighini Rancheria¹⁰, and Yurok Tribe¹¹, have identified the

⁹ Beneficial Uses designated by the Karuk Tribe

¹⁰ Beneficial Uses designated by the Resighini Rancheria

¹¹ Beneficial Uses Designated by the Yurok Tribe

PRELIMINARY REVIEW DRAFT

following existing, potential, and historical beneficial uses within their respective reaches of the Klamath River:

- AGR—Agricultural Supply
- ASQ—Aesthetic Quality⁹
- BIOL—Preservation of Areas of Special Biological Significance^{9, 10}
- COL/COLD—Cold Freshwater Habitat^{9, 10, 11}
- COMM—Commercial and Sport Fishing¹¹
- CUL—Cultural^{10, 11}
- CUL-1—Cultural Contact Water⁹
- CUL-2—Cultural Non-Contact Water⁹
- EST—Estuarine Habitat¹¹
- FC—Fish Consumption⁹
- FRSH—Freshwater Replenishment^{9, 11}
- GW—Groundwater Recharge^{9, 10, 11}
- IND—Industrial Service Supply¹⁰
- LIV—Livestock Watering⁹
- MGR/MIGR—Migration of Aquatic Organisms^{9, 11}
- MGR—Fish Migration¹⁰
- MUN—Municipal and Domestic Supply^{10, 11}
- NAV—Navigation^{9, 11}
- PROC—Industrial Process Supply¹⁰
- PWR/POW—Hydropower Generation^{10, 11}
- RARE/T&E—Rare, Threatened, or Endangered Species^{9, 10, 11}
- REC-1—Water Contact Recreation^{9, 10, 11}
- REC-2—Non-Contact Water Recreation^{9, 10, 11}
- SPAWN—Fish Spawning¹⁰
- SPN/SPWN—Spawning, Reproduction, and/or Early Development^{9, 11}
- WARM—Warm Freshwater Habitat¹¹
- WLD/WILD—Wildlife Habitat^{9, 10, 11}

2.2.2.4 Karuk Tribe, Resighini Rancheria, and Yurok Tribe, Water Quality Objectives and Criteria

The Karuk and Yurok Tribes have established narrative water quality objectives for temperature, DO and nutrients. Additionally, the Tribes have created narrative objectives for toxicity and pH. The Resighini Rancheria has established narrative water quality criteria for temperature and nutrients, as well as toxicity. These narrative water quality standards are quoted in Table 2.3.

Table 2.3: Karuk Tribe, Resighini Rancheria, and Yurok Tribe Narrative Objectives and Criteria for the Klamath River in California

KARUK	
Objective	Description
Temperature	The natural receiving water temperature of intratribal waters shall not be altered unless it can be demonstrated to the satisfaction of the Department of Natural Resources that such alteration in temperature does not adversely affect beneficial uses. At no time or place shall the temperature of any cold freshwater habitat (COLD) water be increased by more than 5 degrees F above natural receiving water temperature.
Dissolved Oxygen	Dissolved Oxygen Concentrations shall not at any time be depressed more than 10 percent from that which occurs naturally.
Nutrients	Biostimulatory Substances: Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.

PRELIMINARY REVIEW DRAFT

Table 2.3 (cont.): Karuk Tribe, Resighini Rancheria, and Yurok Tribe, Narrative Objectives and Criteria for the Klamath River in California

KARUK	
Objective	Description
Toxicity	All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal or aquatic life. Where appropriate, additional numerical receiving water standards for specific toxicants will be established as sufficient data become available, and source control of toxic substances will be encouraged.
pH	Changes in normal ambient pH levels shall not exceed 0.5 units within the range specified in fresh waters with designated COLD or WARM beneficial uses.
RESIGHINI RANCHERIA	
Objective	Description
Temperature	The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Business Council that such alteration in temperature does not adversely affect beneficial uses. At no time or place shall the temperature of any water be increased by more than 5 degrees F above natural receiving water temperature.
Nutrients	Biostimulatory Substances: Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.
Toxicity	All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal or aquatic life.
YUROC	
Objective	Description
Temperature	The temperature of waters within the Yurok Indian Reservation shall not be increased by human caused activity by more than 5 degrees Fahrenheit above the background level at any time or place. If a background level has not been determined, the temperature upstream of a project impacting the receiving water will be considered the background level.
Dissolved Oxygen	Dissolved oxygen concentrations shall not be altered by human caused activities that could cause a barrier to salmonid fish migration or adversely affect the water to support specified beneficial uses.
Nutrients	Ammonia: Levels of ammonia shall not be increased, in any body of water, by human related activity that could cause a nuisance or adversely affect the water to support specified beneficial uses. Biostimulatory Substances: Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses. Nitrites: Levels of nitrites shall not be increased, in any body of water, by human related activity that could cause a nuisance, or adversely affect the water to support specified beneficial uses. Phosphates: Levels of phosphorous in any water body shall not be increased by human related activity above the levels that could cause a nuisance, or adversely affect the water to support specified beneficial uses.
Toxicity	All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life.
pH	Changes related to human caused activities in normal pH levels shall not exceed 0.5 pH units.

Sources: Karuk Tribe of California 2002, Resighini Rancheria Environmental Department 2006, and Yurok Tribe Environmental Program (YTEP) 2004

PRELIMINARY REVIEW DRAFT

In addition to the narrative criteria, the Karuk Tribe, Resighini Rancheria, and Yurok Tribe have established numeric criteria for water quality parameters including temperature, DO, nutrients, and other criteria related to nutrients and toxicity as displayed in Table 2.4, Table 2.5, and Table 2.6.

Table 2.4 Karuk Tribe Numeric Water Quality Objectives

	Temperature (°C)		Dissolved Oxygen (mg/l)		Hydrogen Ion (pH)	
	MWAT ¹	Max	Min	50% lower limit ²	Max	Min
All Streams	15.5	21	-	-	8.5	7.0
Klamath River	-	-	8.0	10.0	-	-
Other Streams	-	-	7.0	9.0	-	-

Sources: Karuk Tribe of California 2002

¹ MWAT is the maximum 7-day average temperature within a given time period.

² 50% lower limits represent the 50 percentile values of the monthly means for a calendar year. 50% or more of the monthly means must be greater than or equal to the lower limit.

Table 2.5 Resighini Rancheria Numeric Water Quality Criteria

	Dissolved Oxygen (mg/l)	Hydrogen Ion (pH)		Microcystis aeruginosa and Microcystin			
		Max	Min	Drinking Water		Recreation Water	
				cells/mL	Microcystin (ug/L)	cells/mL	Microcystin (ug/L)
COLD water column	8.0	-	-	<5000	<1	<50,000	<10
SPAWN intergravel	8.0	8.5	7.0	-	-	-	-
SPAWN water column	11.0	8.5	6.5	-	-	-	-

Source: Resighini Rancheria Environmental Department 2006

¹ 7-DAMin is the minimum 7-day average dissolved oxygen concentration within a given time period.

Table 2.6: Yurok Tribe Numeric Water Quality Objectives

	Temperature (°C)		Dissolved Oxygen (mg/l)		Nutrients		Hydrogen Ion (pH)	
	MWAT ¹	Max	Min	50% lower limit ²	Nitrate (mg/L)	Ammonia (mgN/L)	Max	Min
All Streams	15.5	21.0	7.0	9.0	-	- ³	8.5	6.5
Domestic/Municipal supply	-	-	-	-	10	-	-	-

Source: Yurok Tribe Environmental Program (YTEP) 2004

¹ MWAT is the maximum 7-day average temperature within a given time period.

² 50% lower limits represent the 50 percentile values of the monthly means for a calendar year. 50% or more of the monthly means must be greater than or equal to the lower limit.

³ Maximum one-hour and 30-day average concentrations linked to pH by a formula. Formula can be found in YTEP 2004.

2.3 Water Quality Conceptual Models Overview

There are numerous overlapping physical, chemical, and biological factors that are

PRELIMINARY REVIEW DRAFT

currently contributing to impairment of water quality standards in the Klamath River. The purpose of this section is to describe these factors and discuss how they are contributing to impairment.

The challenge associated with the Klamath River TMDL problem statement is to develop a clear roadmap between the TMDL listing parameters of nutrients, temperature, and DO and their impacts on beneficial uses. There are several issues that must be addressed as part of this challenge. Nutrients and temperature often interact together and with other watershed factors to influence intermediate processes within the aquatic ecosystem that then impact ecological elements that are closely associated with Klamath River beneficial uses. With multiple factors impacting multiple ecosystem components, impacts on beneficial uses can be cumulative and involve effects from several different pathways. The Klamath River problem statement is based on the California Nutrient Numeric Endpoints (CA NNE) framework that incorporates an ecological risk assessment (ERA) process to clearly identify and evaluate impacts on beneficial uses from multiple concurrent stressors.

An ERA evaluates the likelihood that adverse ecological impacts may occur in response to one or more stressors. Keys to a successful ERA are identifying (1) the pathways by which stressors cause ecological effects and (2) informative and representative assessment endpoints. Assessment endpoints are the link between scientifically measurable endpoints and the objectives of stakeholders and resource managers (Suter 1993). Endpoints should be ecologically relevant, related to environmental management objectives, and susceptible to stressors (USEPA 1998). For the Klamath River problem statement evaluation, nutrients and temperature are the primary stressors and separate conceptual models have been developed for each. There are a total of thirty-three assessment endpoints included in the Klamath River nutrient conceptual model, and thirty-one assessment endpoints in the temperature conceptual model. The Klamath River problem statement evaluation includes DO as a secondary indicator in the pathway analysis. The management objectives for the Klamath River conceptual models are the beneficial uses designated to the Klamath River in the Basin Plan.

A corresponding tool of the ERA process is development and evaluation of a conceptual model, and corresponding selection of assessment endpoints. A conceptual model is a graphical and narrative description of the physical, chemical and biological stressors within a system, their sources, and the pathways by which they are likely to impact multiple ecological resources (Suter 1999) and contribute to beneficial use impairment. The conceptual model is important because it links exposure characteristics such as water quality conditions with the ecological endpoints important for describing the beneficial uses.

Conceptual models consist of two general components (USEPA 1998): (1) a description of the hypothesized pathways between human activities (sources of stressors), stressors, and assessment endpoints; and (2) a diagram that illustrates the relationships between human activities, stressors, and direct and indirect ecological effects on assessment endpoints. The conceptual model consolidates available information on ecological

PRELIMINARY REVIEW DRAFT

resources, stressors, and effects, and describes, in narrative and graphical form, relationships among human activities, stressors, and the effects on valued ecological resources (Suter 1999). A conceptual model provides a visual representation for the cases where multiple stressors contribute to water quality problems. With the conceptual model, some attribute or related surrogate (termed an "indicator" in both the watershed approach [USEPA 1995] and the TMDL program) provides a measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality (USEPA 1999a).

2.3.1 Klamath River Nutrient and Temperature Conceptual Models

Figure 2.1 and Figure 2.2 present the nutrient and temperature conceptual models developed for the Klamath River TMDL problem statement. The components of the Klamath River nutrient and temperature conceptual models are described below.

- Driver / Stressor (A) – The primary risk element being evaluated (nutrients and temperature). There is one element, increased nutrient loading, included in this category for the nutrient conceptual model, and five elements in this category for the temperature conceptual model.
- Environmental Conditions (B) – Water quality processes directly impacted by the stressor. These conceptual model “elements” are linked to response/outcome ecosystem elements (e.g., fish populations) that are more directly linked to aspects of the beneficial use. Environmental Condition elements are secondary indicators, providing an intermediate measure (prior to primary impact) of beneficial use condition. There are 12 elements in this category for both the nutrient and the temperature conceptual models respectively.
- Risk Cofactors (C) – In the nutrient conceptual model, these are related conditions or stressors that affect how nutrients are processed in the ecosystem. The nutrient risk cofactors listed in category C can magnify or mitigate the negative impacts linked to nutrients as biostimulatory substances. In the temperature conceptual model, the risk cofactors are processes or factors which are affected by the environmental conditions (category B) caused by an altered natural temperature regime. There are eight nutrient risk cofactors and four temperature risk cofactors identified.
- Response / Outcome - Fish and Aquatic Life (Da) – The elements included in Category Da involve some measure of the health of the Klamath River fish populations and associated impacts to Native American culture and commercial and sport fishing. Other forms of aquatic life could be included in this category, but the cold water fish are considered most sensitive to water quality conditions resulting from increased nutrient loading and altered temperature regimes. There are nine elements in this category for the nutrient conceptual model and 10 for the temperature conceptual model.
- Response / Outcome - Human Health and Aesthetics (Db) – Beneficial uses linked to the human related assessment endpoints are included in category Db. Risk

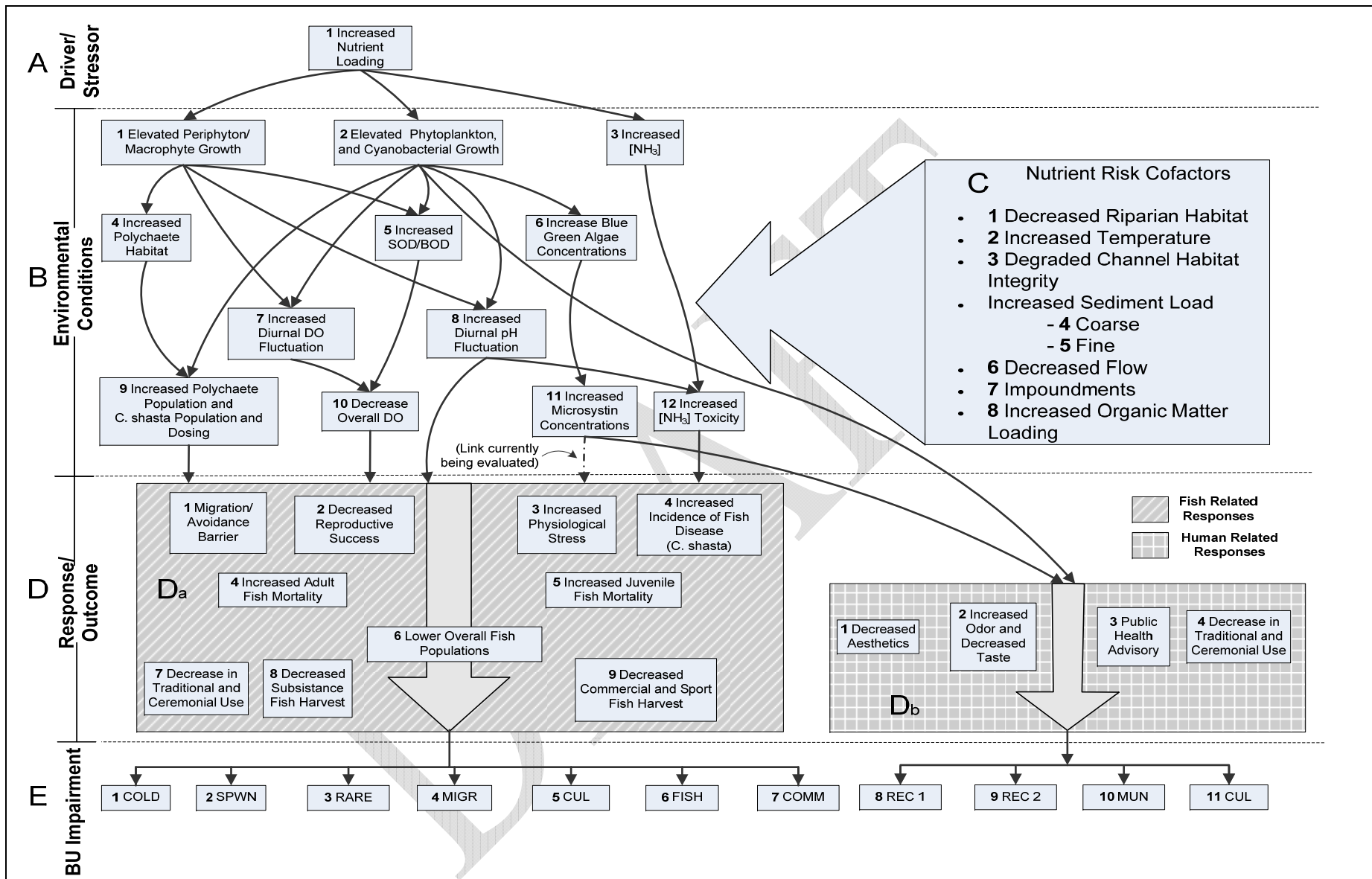


Figure 2.1: Nutrient Conceptual Model for the Klamath River in California

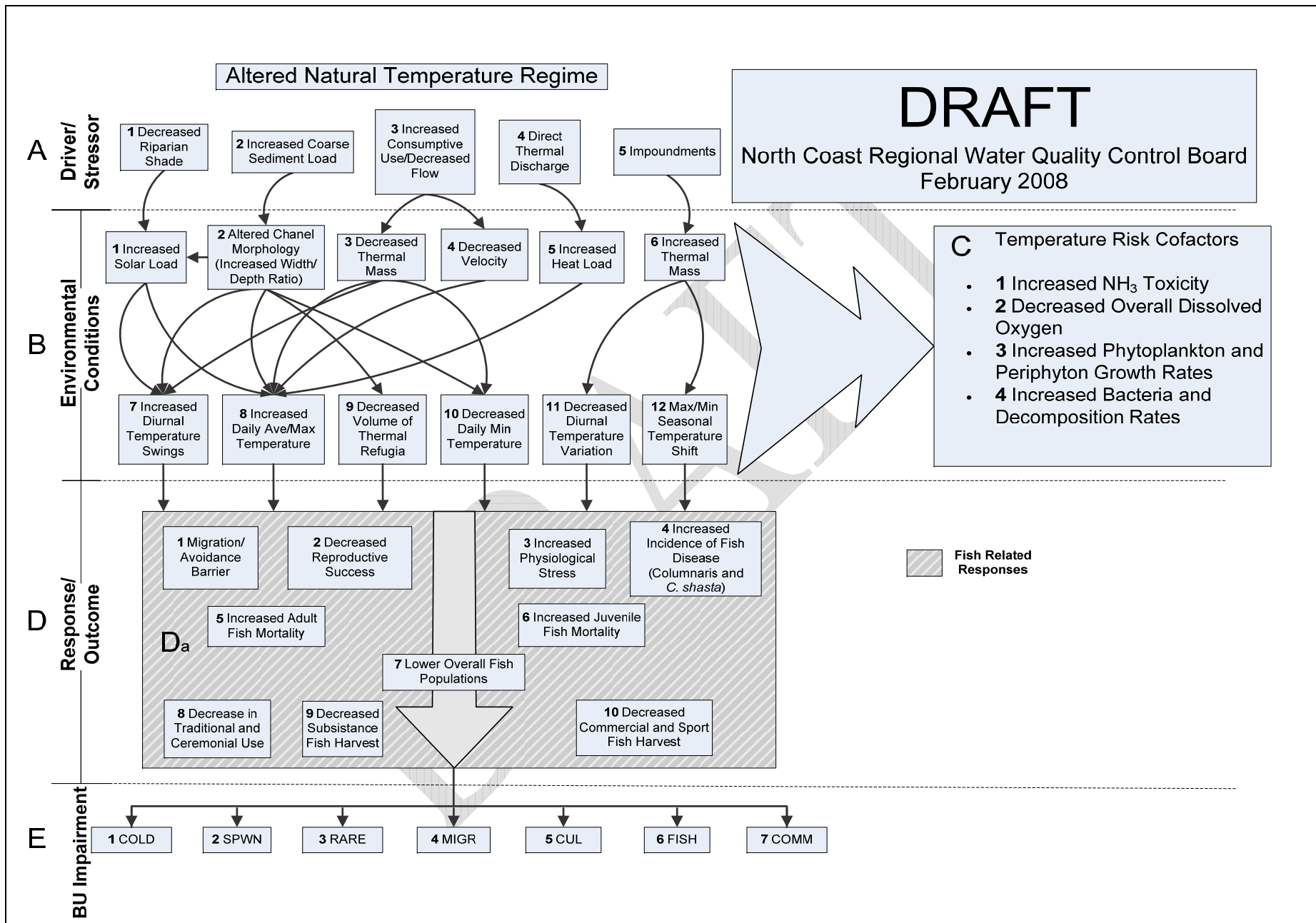


Figure 2.2: Temperature Conceptual Model for the Klamath River in California

PRELIMINARY REVIEW DRAFT

related to close human contact or conditions that prohibit contact are potentially impacting long standing ceremonial practices of Tribes along the Klamath River and disruption of recreational activities. There are three assessment endpoints for this category.

- Beneficial Use Impairment (E) – Category E includes all of the beneficial uses that the California Regional Water Board has determined to be impacted by water quality conditions in the Klamath River basin, and their restoration will be the primary focus of the TMDL implementation plan.

It is not the purpose of the conceptual models developed for the Klamath River TMDL to provide a comprehensive description of all ecosystem elements and pathways. Rather the focus is on identifying assessment endpoints that either should be managed or measured as indicators of water quality condition for attaining and maintaining water quality standards in the Klamath River. The following sections describe the assessment endpoints and the linkages between the assessment endpoints that contribute to impairment of water quality standards in the Klamath River.

In the following sections, when components of the nutrient conceptual model are being discussed they will be referenced with the letter “N”, and when the temperature conceptual model is being discussed it will be referenced with the letter “T”. For example, a discussion related to the environmental condition of increased SOD/BOD from the nutrient conceptual model is referenced as “NB5”, and a discussion of the environmental condition of increased solar loading in the temperature conceptual model is referenced as “TB1”.

2.3.2 Nutrient Conceptual Model Environmental Conditions and Cofactors

The Klamath River prior to anthropogenic impacts was likely a highly productive ecosystem, in part driven by relatively high background loading of nutrients. More recently, anthropogenic impacts have resulted in increased levels of nutrient and organic loading and altered nutrient dynamics that have amplified the risk associated with **increased nutrient loading (NA1)** throughout the basin.

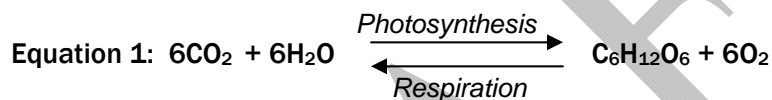
2.3.2.1 Nutrient Related Affects on Productivity

Increased nutrient loading (NA1) can result in increased primary productivity in waterbodies. Ecologically, an increase in primary production can increase the production of invertebrates and fish in streams (MacDonald et al. 1991). However, **elevated periphyton¹² and phytoplankton growth (NB1, NB2)** result in high levels of algal biomass, and through algal respiration and photosynthesis can significantly **increase diurnal DO and pH swings (NB7, NB8)** and result in **decreased overall DO (NB10)** (Welch and Jacoby 2004). In their investigation of water quality conditions on the North Umpqua River, Anderson and Carpenter (1998, p.12) describe the process that occurs in rivers that have significant periphyton communities:

¹² For the purposes of the Klamath River TMDL Problem statement the term periphyton refers primarily to plants that are attached to the substrate (mainly benthic algae). However also included are heterotrophic organisms that are also attached to stream substrate such as bacteria and other benthic macroinvertebrates.

PRELIMINARY REVIEW DRAFT

Photosynthesis, a light driven process (Graham et al., 1982; Wootton and Power, 1993), consumes carbon dioxide (CO₂) and produces oxygen (Equation 1). Respiration by aquatic plants and animals, which occurs at all times, consumes oxygen and produces CO₂. Diel changes in pH are caused by shifts in the carbonate equilibrium (equation 2) as the algae utilize CO₂ (or bicarbonate, HCO₃⁻) during photosynthesis (Wetzel, 1984) faster than atmosphere inputs can equilibrate. Streams with significant periphyton communities often have supersaturated DO concentrations and high pH values late in the day and minimum DO and pH values in the early morning (for examples see Kuwabara, 1992 or Tanner and Anderson, 1996). However the solubility of DO is inversely proportional to the water temperature, which rises in response to solar radiation and thereby decreases DO solubility during daylight hours, and is also impacted by physical reaeration. In effect, stream temperature, reaeration, photosynthesis and respiration compete for control of DO and pH in streams.



The Klamath River has relatively low alkalinity (<100 mg / L) which means that it is a weakly buffered system that is susceptible to photosynthesis driven changes in pH. DO is incorporated into the Klamath River nutrient conceptual model as an assessment endpoint, and not included as a driver/stressor, because DO is an intermediate parameter that responds to the stressors. The actual concentration of DO in water depends not only on saturation concentration (temperature and barometric temperature dependent) but also on oxygen sinks and sources. Two of the primary oxygen sinks are **sediment oxygen demand (SOD) and biochemical oxygen demand (BOD) (NB5)** of substances in the water. When organic matter, such as periphyton and phytoplankton, are broken down by microorganisms in the stream this process consumes oxygen and results in **decreased DO concentrations (NB10)**.

One of the primary fish diseases pathways that has resulted in major documented fish mortalities in the Klamath River in the last several years is illustrated in the pathway: **increased nutrient loading (NA1) → elevated periphyton/macrophyte growth (NB1) → increased polychaete habitat (NB4) → increased polychaete population and *Ceratomyxa shasta* (C. shasta) population and dosing (NB9)**. *Ceratomyxa shasta* is thought to be indigenous to the Klamath River, and is the primary fish health issue in the Klamath River according to USFWS fish health biologist Scott Foott (Foott 2005). The lifecycle of *C. shasta* is complex because the parasite changes form and the lifecycle involves two hosts, a freshwater polychaete (worm) and a salmonid (Figure 2.3). The limiting factor for the presence of *C. shasta* appears to be the presence and abundance of the polychaete in the Klamath River.

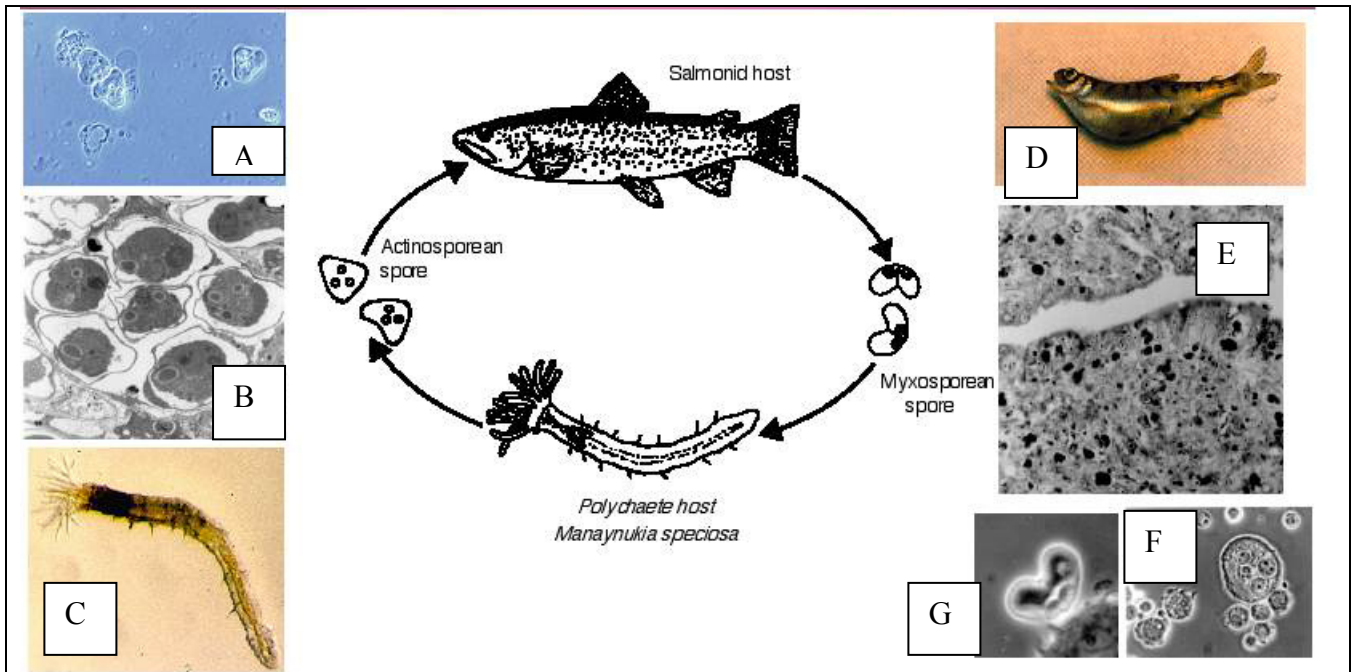


Figure 2.3: Life cycle of *C. shasta* showing release of the myxospore stage from the infected fish, the polychaete alternate host, and release of the alternate actinospore stage from the polychaete. A: released actinospores, B: electron micrograph of actinospores in the polychaete, C: polychaete, D: infected fish, E: histological section of infected intestine, F: trophozoite stages, G: myxospore
Source: Bartholomew et al. 1997 as cited by Stocking and Bartholomew 2004

In 2003 a study by Stocking and Bartholomew (2004) found the highest densities of the polychaete living in periphyton (commonly made up of *Cladophora*). Study results from 2006 at sites located between Iron Gate Dam and Interstate-5 in California revealed that polychaete populations at habitat locations identified in 2004 and 2005 were not present in 2006, or were present in numbers too low to be considered significant (Bartholomew and Stocking 2006). According to Bartholomew and Stocking (2006), the substrate at these locations was new in 2006 and devoid of periphyton (*Cladophora*), most likely due to scour caused by winter flushing flows. It appears that the lack of available habitat for the polychaete in 2006 led to their absence from these locations in the Klamath River.

Based on the above information there may be a linkage between the proliferation of *C. shasta* in the mainstem Klamath River and elevated nutrient concentrations. **Elevated nutrient concentrations (NB)** result in **increased periphyton (NB1)** in the river, which has been identified as prime habitat for the polychaete. **Increased habitat (NB4)** leads to an **increased abundance of the polychaete (NB9)**, which in turn leads to a high infectious spore load in the river. This results in a high probability that adult and juvenile salmonids migrating and rearing in the river will be infected by *C. shasta*.

An additional factor that is potentially shifting the balance toward increased parasite concentrations is the **elevated phytoplankton and cyanobacterial growth (NB2)** in Iron Gate Reservoir, which contributes to **increased polychaete populations (NB9)** in the

PRELIMINARY REVIEW DRAFT

mainstem Klamath River below the reservoir. The polychaetes are filter feeders and feed on various forms of phytoplankton, and most preferably diatoms. **Elevated nutrient loading (NA)** leads to prolific amounts of diatoms and other phytoplankton growth in the reservoir. The diatoms get released into the Klamath River as water flows out of Iron Gate Dam, thus creating an abundant food source for the polychaete, which may contribute to increasing their numbers (USFWS 2006).

Figure 2.4 was presented at the 2008 Klamath River Fish Health Conference to illustrate how the balance between parasite, hosts, and the environment has shifted to favor the increased abundance of parasites. There is an emerging consensus among those conducting research on these relationships in the Klamath River basin that the changes in the environmental conditions identified in the nutrient conceptual model, in association with other risk cofactors, provides a reasonable explanation of the shift to an increasing abundance of parasites (and spores) and higher levels of infection among salmonids in the Klamath River.

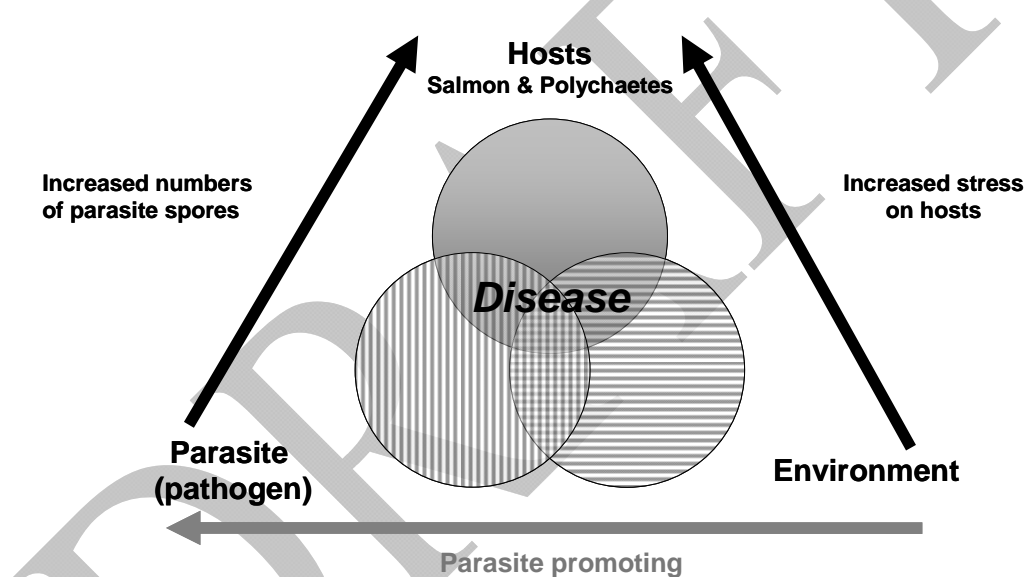


Figure 2.4: Severity of *Ceratomyxosis* in Klamath River suggests a shift in the host/ parasite balance towards *C. shasta* (Bartholomew personal communication 2008).

The increase in the prevalence of parasite infection and related mortality is a very complex issue and it is likely that other environmental factors are also contributing to the proliferation of *C. shasta*. For example, the existing near-constant summer flow regime has not only reduced the frequency of periodic scouring flows, but has also eliminated extreme low flows which could cause the desiccation of the periphyton and resident polychaete populations. An example of the parasite promoting factors included in the conceptual model above is that high densities of salmonids trapped in the reach below Iron Gate leads to increased shedding of the myxosporean spore which then infects the polychaete population in the dense periphyton present downstream of the dam. While these potential factors are not addressed explicitly in the conceptual model, they should be included in any comprehensive assessment and mitigation plan to address this issue.

PRELIMINARY REVIEW DRAFT

The Klamath River basin has also been subject to **excessive phytoplankton and cyanobacteria (blue-green algae) growth (NB2)**. Blue-green algae grow and thrive in slow-moving to stagnant waterbodies such as ponds, lakes, and low gradient river reaches that usually have high nutrient loads accompanied by adequate sunlight. These conditions are found in Copco and Iron Gate Reservoirs, coupled with elevated nutrient concentrations, which promote nuisance **blooms of blue-green algae (NB6)**, particularly *Microcystis aeruginosa* and *Anabaena flos-aquae*.

Both of these species of blue-green algae are capable of producing cyanotoxins. Cyanotoxins produced by these blue-green algae include dermatotoxins (cause contact dermatitis and stomach-intestinal disorders), neurotoxins (cause nervous system poisoning), and hepatotoxins (cause liver poisoning) (WHO 1999, p. 57). **Microcystin (NB11)** is a hepatotoxin produced by *Microcystis aeruginosa*, which has been measured in Copco and Iron Gate and detected in slow moving portions of the river downstream of Iron Gate dam, as well as in Klamath River fish tissue (Fetcho 2006, Kann 2006).

2.3.2.2 Nutrient Related Affects on Ammonia Toxicity

Nutrient loading to a waterbody can contribute directly to **increased ammonia concentrations (NB12)** through the addition of nitrogen to the system. The pH of the water column influences the concentration of un-ionized ammonia (NH_3) and ammonium ion (NH_4^+). As pH increases, un-ionized ammonia concentrations increase and ammonium ion concentrations decrease. These speciation relationships are important to ammonia toxicity because un-ionized ammonia is much more toxic to aquatic species than ammonium ion (USEPA 1999b). The **increased diurnal pH (NB8)** swings result in higher pH levels in the water column, and can result in **increased ammonia toxicity (NB12)**.

2.3.2.3 Nutrient Risk Cofactors

Generally, nutrient concentrations alone do not impair beneficial uses. Rather, in combination with other factors nutrients cause indirect impacts through aquatic plant growth, low DO, high pH, and other related impacts. Nutrients are one factor in the impairment equation that must be present with other risk cofactors to express an impairment. Each of these risk cofactors contribute to the degraded conditions that exist in the Klamath River basin today. Any watershed scale recovery plan must address the potential effect of the following nutrient risk cofactors:

- Reduced riparian habitat (NC1) increases the amount of sunlight that reaches the stream that can drive photosynthesis of both phytoplankton and periphyton. The increased solar radiation also causes **increased temperature (NC2)** of the water column which reduces oxygen saturation potential, and accelerates SOD and BOD processes. Also, reduced riparian habitat can impede riparian functions such as filtering and uptake of pollutants in runoff. These conditions are often associated with **degraded streambank and stream channel conditions (NC3)**.

PRELIMINARY REVIEW DRAFT

- Increased sediment load (NC4, NC5) includes both the fine and coarse components that can originate from different sources (roads versus mass wasting debris flow), but both have similar impacts on the stream ecosystem. Increased sediment load can result in stream channel aggradation, filling in pools and recessed portions of the stream channel (i.e., thalweg), creating a shallow concave channel cross-section that facilitates accelerated growth rates of periphyton and phytoplankton. The transport of sediment into the water column is also a primary mechanism for nutrient loading.
- Altered flow conditions (NC6) covers a wide range of flow impacts including: reduced flow that is more susceptible to high temperature drivers; persistent flow during normally dry conditions which can promote excessive macrophyte and algal growth; reduced scouring flows that can increase periphyton accrual time; and reduced flows can lead to increased rate of deposition of sediment and organic matter in the stream channel.
- Impoundments (NC7) are a significant nutrient risk cofactor because of multiple potential linkages:
 - Empirical data and model predictions indicate that the Copco and Iron Gate impoundments have a small net retention of nutrients, but they play a role in changing the form and timing of nutrients delivered downstream, which may contribute to late season periphyton growth. In addition, under anoxic conditions (i.e., summer stratification) nutrients delivered to the reservoirs in an organic particulate form can be converted to a dissolved inorganic form that is readily available for algal uptake (Welch and Jacoby 2004). There is also an ongoing evaluation of whether reservoirs or free flowing river reaches have a higher nutrient retention / assimilative capacity (Butcher 2008a). Due to incomplete year round monitoring it is not currently possible to perform the nutrient mass-balance analyses required to address this issue with an adequate level of certainty.
 - Impoundments create an environment that is more favorable to nuisance blooms of both green and blue-green algae (Kann and Asarian 2005; Wetzel 2001).
 - As described in section 2.3.2.1, recent studies have resulted in the hypothesis that the high density of the polychaetes below Iron Gate Reservoir may be attributed to enhanced habitat conditions (i.e., dense communities of macroalgae) and waters rich in preferred algal species (diatoms) for the filter feeding polychaetes.
- Increased Organic Matter Loading (NC8) is a risk cofactor in a direct manner by contributing additional nutrients to the Klamath system and by exacerbating stressful DO conditions through SOD and BOD. The increased loading of organic matter is also a risk cofactor in a less direct manner due to its contribution to the formation of anoxic conditions that will alter nutrient dynamics increasing the

PRELIMINARY REVIEW DRAFT

abundance of dissolved inorganic nutrients contributing to increased algal productivity.

2.3.3 Temperature Conceptual Model Environmental Conditions and Cofactors

2.3.3.1 Thermal Processes Related to Solar Loading

Direct solar radiation is the primary factor influencing stream temperatures in summer months. The energy added to a stream from solar radiation far outweighs the energy lost or gained from evaporation or convection (Beschta et al. 1987; Johnson 2004; Sinokrot and Stefan 1993). At a given location, incoming solar radiation is a function of position of the sun, which in turn is determined by latitude, day of the year, and time of day. During the summer months, when solar radiation levels are highest and streamflows are low, shade from streamside forests and vegetation can be a significant control on direct solar radiation reaching streams (Beschta et al. 1987). Because shade limits the amount of direct solar radiation reaching the water, it provides a direct control on the amount of heat energy the water receives. At a workshop convened by the state of Oregon's Independent Multidisciplinary Science Team, 21 scientists reached consensus that solar radiation is the principal energy source that causes stream heating (Independent Multidisciplinary Science Team 2000).

Shade is created by vegetation and topography; however, vegetation typically provides more shade than topography. The shade provided to a water body by vegetation, especially riparian vegetation, has a dramatic, beneficial effect on stream temperatures. The removal of vegetation **decreases shade ($\tau A1$)**, which **increases solar radiation levels ($\tau B1$)**, which, in turn, **increases both average and maximum stream temperatures ($\tau B8$)**, and leads to **large daily temperature variations ($\tau B7$)**. Additionally, the removal of vegetation increases ambient air temperatures, can result in bank erosion, and can result in changes to the channel geometry to a wider and shallower stream channel, all of which also increase water temperatures.

2.3.3.2 Thermal Processes Related to Sediment Load

Increased sediment loads ($\tau A2$) and associated changes in channel morphology can affect stream temperature conditions in multiple ways. These effects can manifest at both large (watershed-wide) and small (individual reach) scales. The implementation plan for the Scott River Sediment TMDL in the Basin Plan (NCRWQCB 2007) defines sediment as: any inorganic or organic earthen material, including but not limited to: soil, silt, sand, clay, and rock.

Increases in sediment loads may lead to a **wider and shallower wetted channel ($\tau B2$)**. In a study of stream channel geometry at twelve gauging stations throughout northwest California, Lisle (1982) described channel widths increasing by as much as one hundred percent, bars becoming smaller, and pools filling in response to increases in sediment supply. Channel widening associated with increased sediment loads can also result in the destruction of riparian canopy and consequent increases in solar loading.

PRELIMINARY REVIEW DRAFT

A wider and shallower channel gains and loses heat more readily than a narrow and deep channel. This principal is true for any stream. A stream's width-to-depth ratio influences stream heating processes by determining the relative proportion of the wetted perimeter in contact with the atmosphere versus the streambed. Also, wide and shallow channels have a greater surface area per unit of volume than a narrower, deeper channel. Water in contact with the streambed exchanges heat via conduction. Conductive heat exchange with the streambed has a moderating influence, reducing daily temperature fluctuations. Water in contact with the atmosphere exchanges heat via evaporation, convection, solar radiation, and long-wave radiation. Heat exchange from solar radiation far outweighs heat exchange from evaporation, convection, and long-wave radiation, unless the stream is significantly shaded. The net effect of changes in width-to-depth ratios is that streams that are wider and shallower heat and cool faster than streams that are narrower and deeper (Poole and Berman 2001).

The effects of a wider and shallower channel are similar to the effects of increased solar loading. Both changes lead to **increases in daily average and maximum temperatures ($\tau B8$), increase diurnal fluctuations ($\tau B7$), and may decrease daily minimum temperatures ($\tau B10$).**

Morphological changes associated with increased sediment loads can also eliminate or result in a **decreased volume of thermal refugia ($\tau B9$)** in a stream or river and impede access to thermal refugia provided by tributaries. Refugial volume can be reduced or eliminated when deep pools fill with sediment, when side channels are buried, or when cold tributary flows percolate into aggraded tributary deltas or gravel bars before entering the river. Similarly, access to refugial tributaries can be reduced or eliminated when sediment loads result in aggradation and cause a tributary to percolate before entering the mainstem or become too shallow for fish to swim. Aggradation has impacted the mouths of Hunter, Terwar, Independence, Walker, Oneil, Portuguese and Grider Creeks, as well as 14 of 17 small Lower Klamath tributaries surveyed by the Yurok Tribe (De La Fuente and Elder 1998; Kier Associates 1999). Finally, refugia can be eliminated when tributary temperatures increase beyond salmonid thresholds due to the effects of increased sediment loads.

Increased sediment loads may also reduce heat exchange associated with hyporheic processes through simplification of the bed topography and reduced permeability due to increases in fine sediment deposition. Several published studies describe effects of sediment on stream channel morphology and stream channel characteristics related to thermal refugia. Vaux (1968) demonstrated that hyporheic exchange is dependent on the topographic complexity of the bed surface and permeability of the sediments. Wondzell and Swanson (1999) similarly demonstrated that simplification of stream channel geometry decreases intra-gravel exchange rates and suggested that loss of pool-step sequences related to channel disturbances could result in decreased intra-gravel exchange.

The complexity of the streambed (e.g. side channels, deep pools, topographic relief) can also influence stream heating processes by affecting the amount of intra-gravel flow, and

PRELIMINARY REVIEW DRAFT

can lead to the existence of pockets of cold water through stratification of deep pools and hyporheic-fed side channels. Stream channels with greater complexity have deeper pools, more prominent riffles, and back-watered side-channels. The amount of water passing through the gravels of a stream bed is proportional to the elevation change from the point the water enters the gravel to the point it leaves the gravel. Thus, streams with prominent pool-riffle morphology exchange more heat via conduction than flat, simplified stream channels.

2.3.3.3 Thermal Processes Related to Flow

Surface water diversions (τA3) decrease the volume of water in the stream, and thereby decrease a stream's capacity to assimilate heat. When water is removed from a stream the **thermal mass (τB3)** and **velocity (τB4)** of the water is decreased. Thermal mass refers to the ability of a body to resist changes in temperature. Basically, less water heats or cools faster than more water. Decreases in velocity increase the time required to travel a given distance, and thus increases the time heating and cooling processes can act on the water. These principles are true for any stream.

The increase in the rate of heating that accompanies a decrease in the volume of flow in a stream can have significant temperature effects. A decrease in thermal mass results in **higher daily high and lower daily low temperatures (τB7, τB8, τB10)**, as well as **higher daily average temperatures (τB8)**. Reduced velocities also result in **higher daily average temperatures (τB8)**.

2.3.3.4 Thermal Processes Related to Direct Thermal Discharges

Direct thermal discharge (τA4) is the discrete addition of heat to a waterbody. Direct thermal discharges occur when water is used in a cooling process, such as in power generation or industrial settings, or when warm materials are placed in a waterbody. In the Klamath basin the main source of direct thermal discharges is related to irrigation tailwater return flows.

Flood irrigation is a common irrigation practice in parts of the Klamath basin, including the Klamath Project area and the Shasta River watershed. When irrigation water is applied to a field in this manner, it generally flows across the field as a thin sheet or in shallow rivulets. As the irrigation water runs across the ground it absorbs heat. When irrigation flows return to a stream, they carry with them the **increased heat load (τB5)** added as they pass through the irrigated lands. California Regional Water Board staff deployed temperature monitoring devices at several Shasta Valley locations with irrigation return flows. Upon review of the monitoring results, it was very difficult to determine when the temperature monitoring probes were exposed to irrigation return flow versus when they were exposed to the air, indicating that the temperature of the tailwater return flows were generally at equilibrium with the air temperature. The net effect of direct thermal discharges is an **increase in both daily average and maximum temperatures (τB8)**.

2.3.3.5 Thermal Processes Related to Impoundments

The water stored behind a **dam (τA5)** functions as **thermal mass (τB6)**, storing heat.

PRELIMINARY REVIEW DRAFT

Because larger volumes of water heat and cool slower than smaller volumes, the large volume of water behind an impoundment acts as a temperature buffer, **reducing daily temperature variations downstream (τB11)**. Similarly, large volumes of water resist **seasonal changes in temperature (τB12)**, and thus delay seasonal temperature changes, resulting in colder temperatures in the spring and warmer temperatures in the fall. In the Klamath River, these effects may extend downstream to the Pacific Ocean under certain conditions (Bartholow et al. 2005). The effects are most pronounced immediately downstream of Iron Gate Dam, diminishing in the downstream direction.

The expected biological implications of the changes in diurnal temperature patterns caused by dams are mixed. The **reduced diurnal temperature variation (τB11)** associated with dams lead to reduced peak temperatures, thereby reducing the most acutely harmful temperatures. Conversely, the increased daily low temperatures associated with dams could reduce the time available for fish to leave thermal refugia to feed. Also, higher daily low temperatures may lead to higher temperatures at the bottom of thermally stratified pools (Nielsen et al. 1994).

The **seasonal temperature changes (τB12)** caused by the dams may also have biological implications. Bartholow et al. (2005) evaluated the thermal effects of the Klamath River dams on downstream reaches and determined that the dams delay the seasonal temperature patterns by approximately 18 days on an annual basis. The physical implication of an 18 day shift in the seasonal temperature pattern is that the river is cooler in the springtime when juvenile salmonids are migrating to the ocean, and warmer in the fall when adults are migrating upstream and spawning, and eggs are incubating in the gravels. Cooler temperatures are known to reduce juvenile salmonid growth rates; however this effect may be mitigated by the benefit gained by reduced incidence of stressfully high temperatures during outmigration. Warmer temperatures in the summer period may reduce the nocturnal feeding opportunities of juvenile salmonids that persist at thermal refugia, thereby reducing their ability to withstand stressfully high daytime temperatures (NRC 2004). Warmer temperatures in the fall may delay adult migration or lead to stressfully high temperatures when adults are present or eggs are incubating in gravels. More discussion of this topic can be found in Section 2.4.2.1.

2.3.3.6 Temperature Risk Cofactors

Adverse temperature conditions may combine with other factors to further impair beneficial uses beyond the primary effects of high temperatures. Temperature is a physical factor that affects chemical concentrations and biological growth rates of other factors that affect habitat and water quality. These factors are described below. Each of these risk cofactors contribute to the degraded conditions that exist in the Klamath River basin today. Any watershed scale recovery plan must address the potential effect of the following temperature risk cofactors:

- **Increased NH₃ Toxicity (τC1)** – The concentration of un-ionized ammonia (NH₃) depends on concurrent conditions of high temperature, high pH, and high concentration of ionized ammonia (NH₄⁺). In waterbodies that have high concentrations of ionized ammonia and frequent excursions of high pH, such as the

PRELIMINARY REVIEW DRAFT

Klamath River, an increase in temperature can result in the formation of un-ionized ammonia, which is toxic to fish and other organisms.

- Decreased Overall Dissolved Oxygen (TC2) – The concentration of DO in water is partly a function of the temperature of the water. Colder water can absorb more DO than warm water, if all other factors are equal.
- Increased Phytoplankton and Periphyton Growth Rates (TC3) – Algal growth rate is partially dependent on the temperature at which they grow. Generally, Higher temperatures result in higher rates of growth (up to limiting temperature), if all other factors are equal.
- Increased Bacteria and Decomposition Rates (TC4) – The rate at which bacteria grow and decay is partially dependent on the temperature of the water they are in. Higher temperatures result in higher rates of growth and decay, if all other factors are equal, resulting in greater oxygen demand within the surrounding water column.

2.3.4 Responses/Outcomes

The driver/stressors and environmental conditions discussed in the previous sections have resulted in the response/outcomes identified in Section D of the Nutrient and Temperature Conceptual Models. Many of these have been well documented and are discussed in the following sections, which describes impacts to Klamath River beneficial uses. The current conditions of many of the indicators described in this section will be presented in Section 2.4 to better assess their actual impact on beneficial uses within the Klamath River basin. Additional information on the effects of an altered natural temperature regime and the secondary effects of elevated nutrient levels on salmonids is available in Appendix 1, (*Effects of Temperature, Dissolved Oxygen/Total Dissolved Gas, Ammonia, and pH on Salmonids*).

2.3.4.1 Migration/Avoidance Barrier (Da1)

High water temperatures can inhibit or block upstream migration of adult salmonids. One study specific to the Klamath River was conducted by Strange (2007) and evaluated the association between water temperature in the mainstem Klamath River and adult fall Chinook migration. Utilizing radio telemetry to track the movements and monitor the internal body temperatures of adult fall Chinook salmon during their upriver spawning migration in the Klamath basin, Strange (2007) found that fall Chinook will not migrate upstream when mean daily temperatures are $\geq 22^{\circ}\text{C}$. Strange also noted that adult fall Chinook in the Klamath basin will not migrate upstream if temperatures are 21°C or above and rising, but will migrate at temperatures as high as 23°C if temperatures are rapidly falling.

The upstream migration by adult salmonids is typically a stressful endeavor. Sustained swimming over long distances requires high expenditures of energy and therefore requires adequate levels of DO. Migrating adult Chinook salmon in the San Joaquin River exhibited an avoidance response when DO was below 4.2 mg/L, and most Chinook waited to migrate until DO levels were at 5 mg/L or higher (Hallock et al. 1970). The

PRELIMINARY REVIEW DRAFT

swimming performance of migrating salmonids is also impacted by reduced concentrations of DO (Bjornn and Reiser 1991).

2.3.4.2 Decreased Reproductive Success (Da2)

There is evidence that fish that oversummer in stressfully high temperatures and low DO concentrations experience reduced reproductive success (Coutant 1987). A study by Coutant (1987) demonstrates that fish experiencing the combination of high temperatures and low DO are subject to physiological harm that persists well after the fish are exposed to these water quality conditions. Persistent effects of high temperature and low DO include a reduction in female spawning success and poor embryo survival.

2.3.4.3 Increased Physiological Stress (Da3)

Increased temperature and the secondary effects of nutrient loading can result in physiological stress on salmonids. The metabolic processes of salmonids are directly related to temperature. When water temperatures are above the optimal metabolic range for salmonids, the resting metabolic rate increases dramatically. This results in reduced feeding rates, swimming speed, growth, reproduction, and resistance to environmental extremes (USEPA 2001, p.39). Also, if temperatures are high, much of the energy assimilated from food is lost as excessive metabolism (USEPA 2001, p.85). High incubation temperatures may create a metabolic energy deficit for pre-emergent salmon that increases mortality (Heming 1982, as cited by USEPA 2001, p.31). Further, the stressful impacts of water temperatures on salmonids are cumulative and positively correlated to the duration and severity of exposure. The longer the salmonid is exposed to thermal stress, the less chance it has for long-term survival (Ligon et al. 1999).

As the metabolic rates of salmonids increase there is an increased physiologic demand for oxygen. Low DO concentrations (<4-5 mg/L) result in decreased size of newly hatched salmonids (WDOE 2002, p.14), as well as decreased juvenile salmonid growth and food consumption (Bjornn and Reiser 1999, p.118; Herrmann et al. 1962; and USEPA 1986, p.5-8), and decreased food conversion efficiency (ODEQ 1995, p.A-6). When DO levels are extremely low (2-3 mg/L) weight loss can occur due to decreased food consumption (Herrmann et al. 1962). Low DO concentrations also adversely affect swimming performance in both adult and juvenile salmonids (Bjornn and Reiser 1999, p.85, 118, 119; WDOE 2002, p.46).

Concentrations of ammonia acutely toxic to fishes may cause loss of equilibrium, hyperexcitability, increased breathing, cardiac output and oxygen uptake, and, in extreme cases, convulsions, coma, and death. At lower concentrations ammonia has many effects on fishes, including a reduction in hatching success, reduction in growth rate and morphological development, and pathologic changes in tissues of gills, livers, and kidneys (USEPA 1986, p.17).

The pH of freshwater streams, lakes, and reservoirs is also important for adult and juvenile salmonid development, and is influenced by the respiration of benthic algae and phytoplankton. Chronic effects from low pH can occur at levels that are not toxic to adult fish but that impair reproduction including altered spawning behavior, reduced egg

PRELIMINARY REVIEW DRAFT

viability, decreased hatchability, and reduced survival during early life stages when salmonid development is most vulnerable to low pH (Jordahl and Benson 1987). Chronic high pH levels in freshwater streams can decrease activity levels of salmonids, create stress responses, decrease or cease feeding, and lead to a loss of equilibrium (Murray and Ziebell 1984; Wagner et al. 1997). Additionally, high temperatures can exacerbate the effects of high pH levels on salmonids, and if pH reaches extremely low or high levels, death can occur (Wagner et al. 1997).

2.3.4.4 Increased Incidence of Fish Disease (*Ceratomyxa Shasta* and *Columnaris*) (D_a4)

The USFWS California-Nevada Fish Health Center has identified *C. shasta* as the primary fish health issue in the Klamath River, and *Columnaris* is the second biggest fish health threat (Foott 2005). Disease has been cited as the ultimate cause of death in most of the adult and juvenile fish kills which have occurred in the Klamath River from Iron Gate Dam to the mouth (CDFG 2000; CDFG 2004; Deas 2000; Engbring 2004; Foott 2000; Foott et al. 2002; Hannum 1997; Hendrickson 1997; KFHAT 2005; Klamt and Carter 2004; USFWS 1997; USFWS 2003a; USFWS 2003b; Williamson and Foott 1998). On more than one occasion the outbreak of disease was termed an “epizootic” (the equivalent of an epidemic in humans), and in all cases the disease outbreaks were exacerbated by a combination of poor water quality conditions including high water temperatures, low DO levels, sediment deposition, and high ammonia concentrations (CDFG 2000; CDFG 2004; Deas 2000; Engbring 2004; Foott 2000; Foott et al. 2002; Foott 2005; Hannum 1997; Hendrickson 1997; KFHAT 2005; Klamt and Carter 2004; USFWS 1997; USFWS 2003a; USFWS 2003b; Williamson and Foott 1998).

The USEPA (2003) and Washington Department of Ecology (WDOE 2002, p.115) report that as water temperatures increase, the risk and severity of a disease outbreak increases. The infectivity of *C. shasta* and *Columnaris* increases with increasing temperature, and the lifecycle of these diseases shorten with increasing temperature, making outbreaks more likely. WDOE (2002) expresses the temperature thresholds that are likely to prevent or exacerbate disease outbreaks as a Maximum Weekly Maximum Temperature (MWMT), which is the maximum seasonal or yearly value of the daily maximum temperatures over a running seven-day consecutive period. The Washington Department of Ecology (WDOE 2002, p.115) conducted a review of studies on disease outbreak in salmonids and estimate that a MWMT of less than or equal to 14.4°C (midpoint of 12.6-16.2 range) will virtually prevent warm water disease effects. According to WDOE (2002, p.115), to avoid serious rates of infection and mortality the MWMT should not exceed 17.4°C (midpoint of 15.6-19.2 range), and that severe infections and catastrophic outbreaks become a serious concern when the MWMTs exceed 21.0°C (midpoint of 18.6-23.2 range). In a summary of temperature considerations, USEPA (2003) state that disease risks for juvenile rearing and adult migration are minimized at temperatures from 12°C to 13°C, elevated from 14°C to 17°C, and high at temperatures from 18°C to 20°C. Additionally, the crowding of salmonids in thermal refugia increases the likelihood of fish-to-fish transmission of *Columnaris*.

When the infectious spore load of *C. Shasta* in the Klamath River is low or juvenile salmonids are exposed for less than 24 hours, they can successfully rear at temperatures

PRELIMINARY REVIEW DRAFT

as high as 21°C (Foott 2006). However, if the infectious spore load in the river is high or juvenile salmonids are exposed for long periods of time (2-4 days), mortality occurs at temperatures as low as 16°C (Foott 2006).

As discussed in Section 2.3.2.1 there may be a linkage between the proliferation of *Ceratomyxa Shasta* (*C. Shasta*) in the mainstem Klamath River and elevated nutrient concentrations. Elevated nutrient concentrations allow for the proliferation of prime polychaete habitat (periphyton) and thus large numbers of polychaetes and high infectious spore load in the river. This can lead to an increased probability of *C. shasta* infections.

2.3.4.5 Increased Fish Mortality and Lower Overall Populations (Da4, Da5, Da6)

The effects of altered temperature, decreased DO, and increased nutrient loading can have a significant impact on salmonids. In the Klamath River basin, the impacts of high water temperature directly, and in combination with other factors, have likely resulted in both adult and juvenile fish mortality and contributed to lower overall fish populations.

Bartholow (1995, p.19) states, "...water temperatures in the Klamath basin are marginal at best for anadromous salmonids, squeezing their thermal resources in both space and time." The National Research Council of the National Academies (NRC) state that various factors including decreased flows and increased water temperatures in the Klamath River basin have contributed to declining salmonid populations during the 20th century (NRC 2004, p.284). Salmonid populations in the Klamath River basin have declined sharply since the early 1900's. In 1931, Snyder (1931, p.9 121) wrote that the fishery of the Klamath River basin is very important because with proper management it can be maintained, although he also states that depletion of the Klamath salmon is apparent and occurring at an "alarming rate" which artificial propagation alone may not remedy. The NRC (2004, p.284) reports that virtually all Klamath River basin populations of salmonids have declined considerably from their historical abundances, and note the significant link between the decline in coho, spring Chinook, and summer steelhead to the "verge of extinction" and their dependence on cool summer water temperatures. The NRC also notes that the Klamath River has become inhospitable to juvenile coho due to high water temperatures, and although the Klamath River is still important for rearing Chinook and steelhead, further increases in temperatures may make it unsuitable even for those species (NRC 2004, p.284). NRC (2004, p.268) state that in some respects, "...it is remarkable that fall-run Chinook salmon in the Klamath River are doing as well as they seem to be. Both adults migrating upstream and juveniles moving downstream face water temperatures that are bioenergetically unsuitable or even lethal." In 1991, the Klamath River Basin Fisheries Task Force (KRBFTF) identified increased stream temperatures in the lower Klamath River as impeding the recovery and posing threats to coho, winter steelhead, and late run fall Chinook (KRBFTF 1991, p.4-29). A discussion of how temperature and other water quality factors are contributing to fish mortality and salmonid population decline can be found in Section 2.5.1.

2.3.4.6 Impacts to Cultural and Harvest-Related Activities (Da7, Da8, Da9)

The reduction of overall salmonid populations impacts the availability of fish for

PRELIMINARY REVIEW DRAFT

commercial, sport, and subsistence fish harvesting, as well as traditional and ceremonial uses. All of these activities require robust fish populations for long-term sustainable use of the resource. Thus, water temperatures, DO, pH, and ammonia toxicity outside the range of salmonid suitability can significantly impact these activities. Evidence of temperature and nutrient related impairment to harvest related activities is presented in Sections 2.5.2 and 2.5.4.

2.3.4.7 Impacts to Municipal Supply, Recreation, and Traditional/Cultural Use (Db1, Db2, Db3, Db4)

Elevated nutrient concentrations in the Klamath River basin have contributed to nuisance blooms of the blue-green algae *Microcystis aeruginosa*, which produces the cyanotoxin microcystin. Exposure routes of cyanotoxin poisoning can be via direct water contact, ingestion of contaminated water, breathing of aerosolized toxin bearing water, and possibly secondarily through the ingestion of infected fish or other vertebrates, invertebrates, and plant matter. As detailed in Section 2.4.4 this toxin has been detected in Copco and Iron Gate Reservoirs at levels which are considered dangerous for contact or consumption, leading to the posting of public health warnings at the reservoirs and various locations along the river.

The Klamath River Tribes utilize the river for traditional and ceremonial uses including bathing, plant gathering, ingestion, and other activities discussed in Section 2.5.2. The presence of microcystin in the lower river presents a potential human health risk for the Tribes. Further, mats of phytoplankton in the reservoirs and river are an aesthetic nuisance impacting the public's ability to enjoy the natural beauty of these waters. Additionally, taste and odor problems are associated with high densities of cyanobacteria, and these compounds are difficult and costly to remove from water supplies (Welch and Jacoby 2004, p.172).

2.4 Evidence of Water Quality Objective Exceedances

This section presents observed water quality conditions and evaluates the data with respect to the relevant water quality objectives or surrogate thresholds.

2.4.1 *Temperature and Nutrient Data Sources*

Stream temperature data used for this analysis were provided by the US Forest Service, Yurok Tribe, Karuk Tribe, Forest Science Project, US Fish and Wildlife Service, Salmon River Restoration Council, and PacificCorp. In addition, California Regional Water Board staff collected temperature data.

For the DO and nutrient analyses California Regional Water Board staff compiled monitoring data from several sources including the US Fish and Wildlife Service, US Geological Survey, PacificCorp, Karuk Tribe, Yurok Tribe, California Regional Water Board, and the US Environmental Protection Agency Environmental Monitoring and Assessment Program.

PRELIMINARY REVIEW DRAFT

2.4.2 Temperature

California Regional Water Board staff conducted a literature review to evaluate stream temperature requirements for the various life stages of steelhead trout (*Oncorhynchus mykiss*), coho salmon (*Oncorhynchus kisutch*), and Chinook salmon (*Oncorhynchus tshawytscha*) as a means for interpreting the narrative temperature objective in the Basin Plan (NCRWQCB 2007). As a result of this literature review, California Regional Water Board staff selected chronic and acute temperature thresholds for evaluating Klamath River basin temperatures.

Chronic temperature thresholds were selected from the USEPA document *EPA Region 10 Guidance For Pacific Northwest State and Tribal Temperature Water Quality Standards* (2003), and are presented in Table 2.7. The Region 10 guidance is the product of a three-year interagency effort, and has been reviewed by both independent science review panels and the public. Acute lethal temperature thresholds were selected based upon best professional judgment of the literature, and are presented in Table 2.8. These freshwater temperature thresholds are applicable during the time of year when the life stage of each species is present in the Klamath River basin. Where life history, timing, and/or species needs overlap, the lowest of each temperature metric applies. A discussion of the distribution and periodicity of salmonids in the Klamath River basin is available in Appendix 2. Additional information on the effect of temperature on salmonids and a brief discussion of temperature metrics are available in Appendix 1.

Table 2.7: MWMT Chronic Effects Temperature Thresholds

Life Stage	MWMT (°C)
Adult Migration	20
Adult Migration plus Non-Core Juvenile Rearing ¹	18
Core Juvenile Rearing ²	16
Spawning, Egg Incubation, and Fry Emergence	13

Source: USEPA 2003

¹ The Adult Migration plus Non-Core Juvenile Rearing designation is recommended by USEPA (2003) for the “protection of migrating adult and juvenile salmonids and moderate to low density salmon and trout juvenile rearing during the period of summer maximum temperatures,” usually occurring in the mid to lower part of the basin. The phrase “moderate to low density” is not specifically defined.

² The Core Juvenile Rearing designation is recommended by USEPA (2003) for the “protection of moderate to high density summertime salmon and trout juvenile rearing” locations, usually occurring in the mid to upper reaches of the basin. The phrase “moderate to high density” is not specifically defined.

Table 2.8: Lethal Temperature Thresholds

Lethal Threshold ¹ (°C)			
Life Stage	Steelhead	Chinook	Coho
Adult Migration and Holding	24	25	25
Juvenile Growth and Rearing	24	25	25
Spawning, Egg Incubation, and Fry Emergence	20	20	20

¹ The lethal thresholds selected in this table are generally for chronic exposure (greater than seven days). Although salmonids may survive brief periods at these temperatures, they are good benchmarks from the literature for lethal conditions.

PRELIMINARY REVIEW DRAFT

2.4.2.1 Mainstem Klamath River

Temperature data from the Klamath River mainstem indicate that seasonal maximum temperatures are not supportive of beneficial uses. Figure 2.5 shows that MWMt values at all sites from the Oregon-California state line to the estuary are well above the suitable temperature range for full support of salmonids as described by USEPA (2003). These data clearly demonstrate that the river has no capacity to assimilate increased heat loads during the hottest critical periods without adversely affecting the beneficial uses COLD, SPWN, RARE, and MIGR.

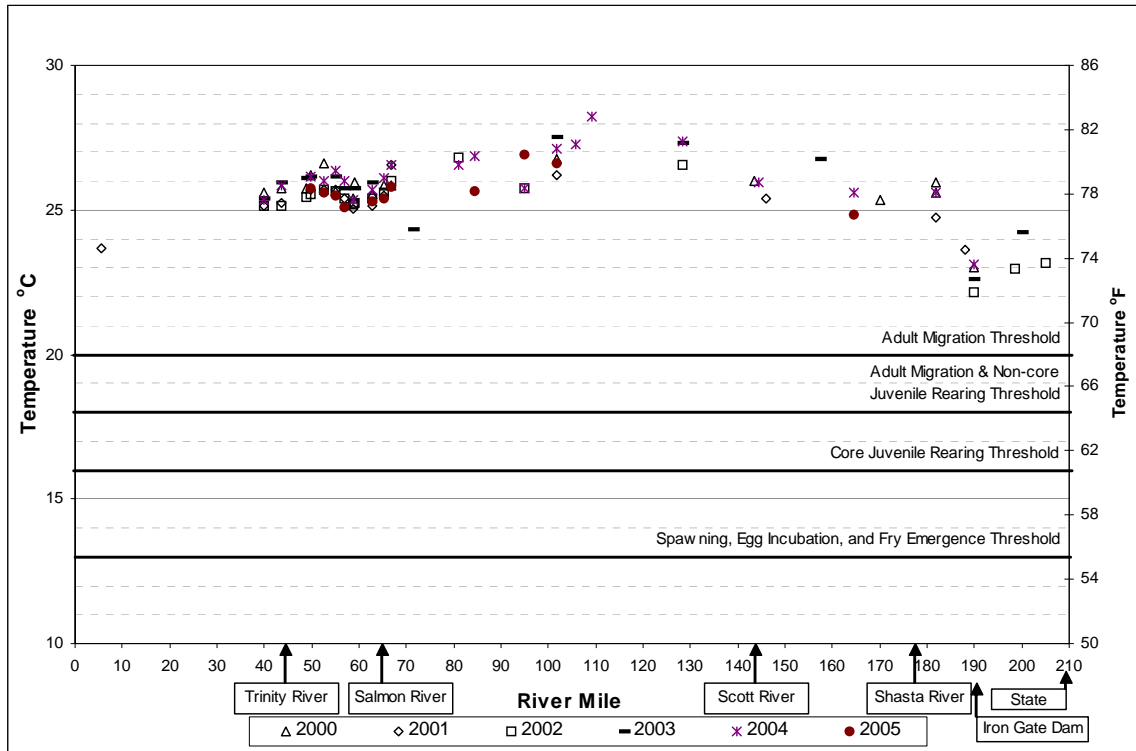


Figure 2.5 : Measured Klamath River MWMt, 2000-2005.

Note: MWMt typically occur in late July.

The results of water quality modeling completed for this TMDL process indicate that human activities have significantly altered the temperature regime of the mainstem Klamath River. The application of the water quality models is described in Chapter 3. These results indicate that the combined effects of human activities in the basin commonly result in temperature alterations in excess of 5 °F, and these alterations can be as much as 18 °F. Figure 2.6 presents simulated natural and current Klamath River temperatures, and the calculated difference, at the site of maximum temperature alteration in California.

The temperature modeling indicates human impacts adversely affect both the rearing of juvenile salmonids and the reproductive success of adult salmonids. Under current conditions, the increase in temperatures during the winter and spring months is delayed in comparison to estimated natural temperatures. Similarly, the decrease in temperatures during the fall months is also delayed in comparison to estimated natural temperatures.

PRELIMINARY REVIEW DRAFT

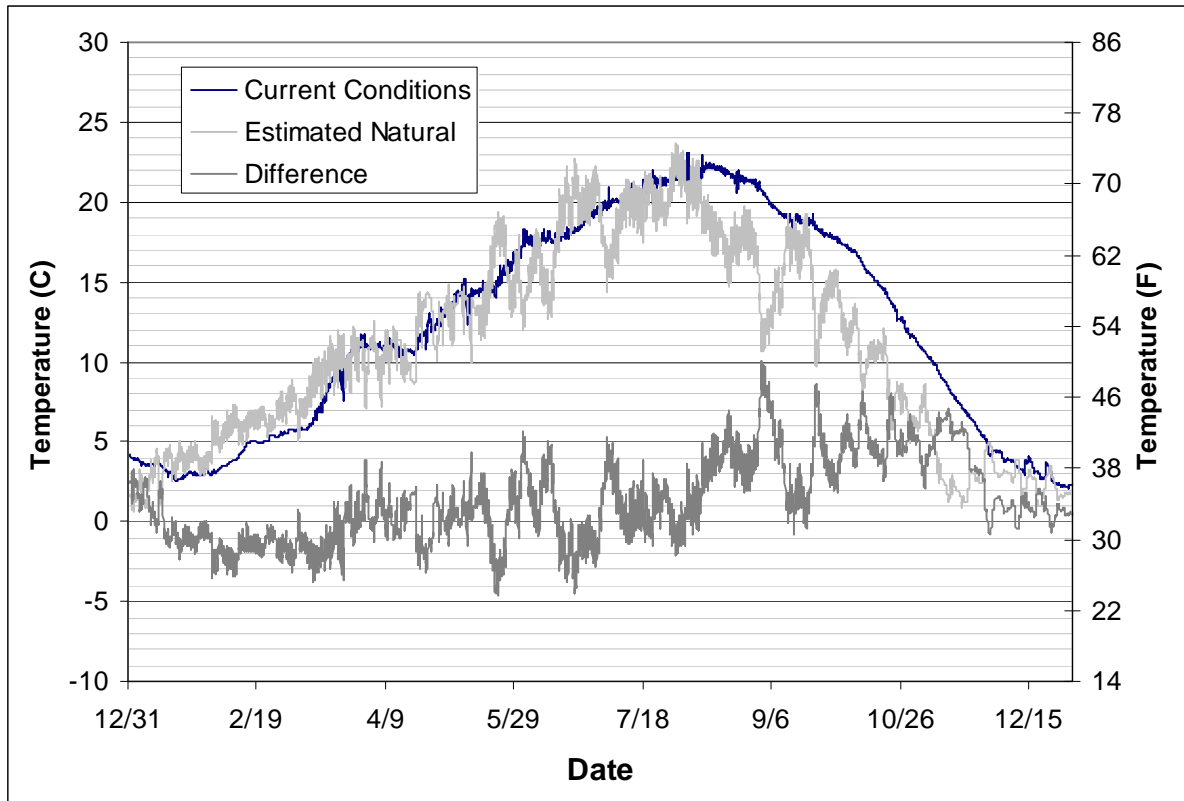


Figure 2.6: Current and Estimated Natural Temperatures Downstream of Iron Gate Dam, 2000
Note: Model results presented at 1-hour time step.

The growth of juvenile salmonids is partially dependent on temperature (USEPA 2003). The optimal temperature range for juvenile salmonids is 10-15 °C, with a lower limit of 4 °C (USEPA 2003). The ability of salmonids to survive the ocean phase of their life cycle is partially dependent on their size upon entering the ocean. Thus, the delay in springtime warming reduces the growth rates of salmonids rearing in the Klamath River, and may ultimately reduce the survival rate of salmonids in the ocean.

USEPA (2001) reviewed multiple literature sources and concluded that optimal protection of salmonids from fertilization through initial fry development requires that temperatures be maintained below 9-10°C, and that daily maximum temperatures should not exceed 13.5-14.5°C. Under current conditions, these temperatures are not reached until late October or November. However, the Chinook spawning season begins in mid-September and peaks in late October (see Appendix 2 for more details).

Bartholow et al. (2005) concluded that in comparison to the expected temperatures resulting from a natural flow regime, the Klamath River dams create temperature conditions more favorable to migrating juveniles in the spring and less favorable to adults migrating and spawning in the fall. The authors further speculated that the changes in seasonal temperature patterns may have affected the timing of the Chinook salmon run since the dams were constructed.

PRELIMINARY REVIEW DRAFT

In summary, the temperature alterations presented in Figure 2.6 result in adverse effects to salmonids. The comparison of estimated natural and current temperatures for the year 2000 at the location downstream of Iron Gate Dam clearly shows that the water quality objective for temperature is regularly exceeded. This conclusion is based on the observation that current temperatures are regularly more than 5°F above the estimated natural temperatures, and the fact that there is no capacity to assimilate increased heat loads during the hottest critical periods without adversely affecting the beneficial uses.

2.4.2.2 Tributaries to the Klamath River

Temperature data from the mouths of Klamath tributaries indicate that the seasonal maximum temperatures of the majority of the tributaries are not supportive of beneficial uses. The MWMT values at most of these sites are well above the suitable temperature range for salmonids (Figure 2.7).

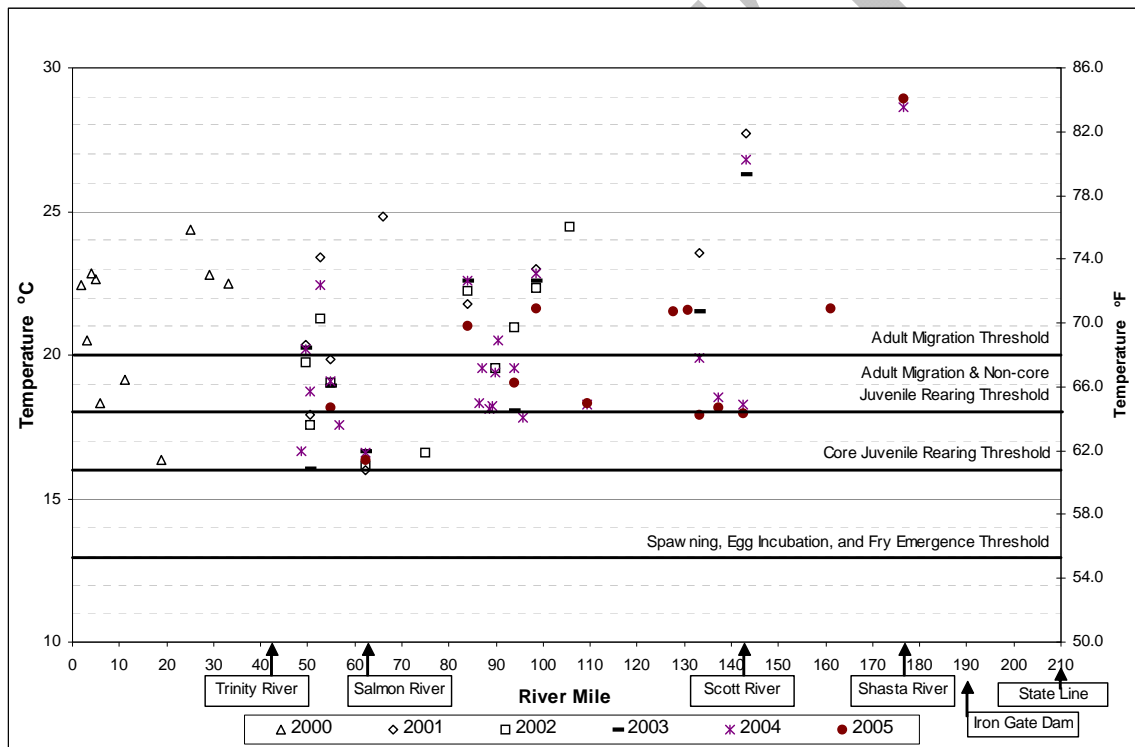


Figure 2.7: Klamath River Tributary Mouth MWMTs Stream Temperatures 2000-2005

Note: MWMTs typically occur in late July.

Of the twenty-two tributaries monitored in 2004 (the year with the most tributaries monitored), eighteen had MWMT values in excess of the adult migration and non-core juvenile rearing thresholds for salmonids (USEPA 2003). These data clearly demonstrate that these tributaries have no capacity to assimilate increased heat loads during the hottest critical periods without adversely affecting beneficial uses.

The Shasta, Scott, and Salmon Rivers, three of the largest Klamath River tributaries, have been listed on the 303(d) list for temperature impairment separately. TMDL analyses developed for these tributaries have confirmed the temperature impairments, as well as

PRELIMINARY REVIEW DRAFT

the human contribution to elevated temperatures in these basins.

Although the temperatures are high relative to the temperature requirements of salmonids (USEPA 2003), the high temperatures do not exceed the water quality objective for temperature unless they are elevated due to human activities, such as riparian vegetation removal and altered channel morphology. However, it is well documented that the erosion associated with the 1997 flood in the Klamath River basin resulted in widespread stream channel alteration, loss of riparian vegetation, and shade reductions (further discussed in Section 2.4.8) and that a significant amount of the erosion was caused or exacerbated by human activities (De La Fuente and Elder 1998). Similarly, it is well known that historic mining, road building, and silvicultural practices have resulted in riparian disturbances and consequent reductions of stream shade in many tributaries (Elder et al. 2002; KNF 1999; KNF 2002). Therefore, California Regional Water Board staff conclude that enough information exists to confirm impairment and justify TMDL development and implementation.

2.4.2.3 Reservoirs

The available Iron Gate and Copco Reservoir temperature and DO profile data indicate that during summer stratified conditions temperatures are only suitable for cold water species, including salmonids, rearing at depths where the DO concentrations are near lethal levels. An example of typical summer conditions is illustrated in the vertical profiles of DO concentration and temperature that are presented in Figure 2.8 for Iron Gate Reservoir.

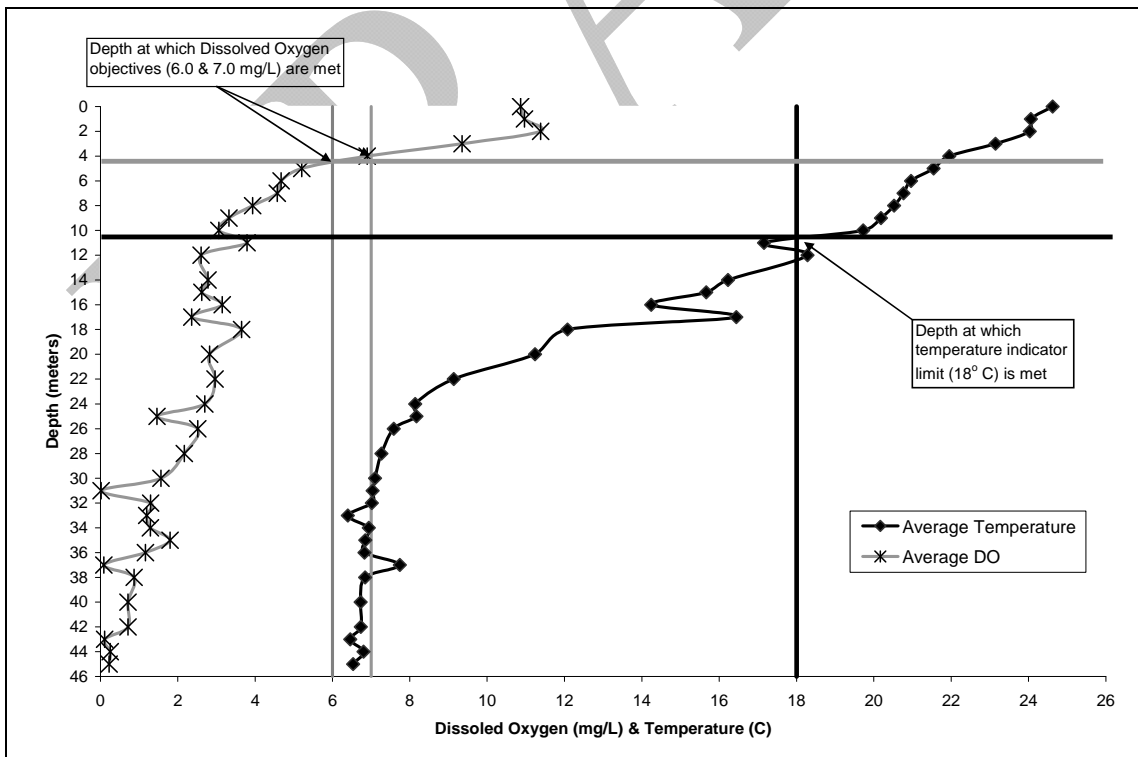


Figure 2.8: Dissolve oxygen and temperature depth profiles in Iron Gate Reservoir for the time period July and August 2005

PRELIMINARY REVIEW DRAFT

The same pattern exists for Copco and for other years. The reservoirs become thermally stratified in the summer months. The stratification of the reservoirs prevents mixing of the low temperature / low DO waters with the high temperature / high DO waters, thus there is no depth in the reservoirs at which the most sensitive beneficial uses are supported. Given that the stratification and the absence of suitable habitat is due to the presence of the reservoirs, California Regional Water Board staff have concluded that the reservoirs contribute to exceedances of the temperature and DO water quality objectives.

2.4.3 Nutrient and Indicators of Nutrient Related Impairment

Except in extreme cases, nutrients alone do not impair beneficial uses. Rather, they cause indirect impacts through their biostimulatory effect on algal growth, low DO, and extreme pH conditions among others that can impair uses. The water quality objectives with distinct numeric limits include DO and pH. The California Nutrient Numeric Endpoints (CA NNE) framework (Tetra Tech 2006) identifies indicators for biostimulatory effects that can impair beneficial uses, including benthic algal biomass, planktonic chlorophyll-a concentrations, and diurnal DO and pH fluctuations. Other indicators included here are toxic blue-green algae (*microcystin*) concentrations, and un-ionized ammonia.

2.4.3.1 Nutrient Concentrations

The primary driver for the nutrient conceptual model is the increased loading of nutrients to the Klamath River ecosystem. High levels of nutrient loading and elevated water column concentrations do not alone result in biostimulatory conditions, but excess nutrients are an essential precondition to this finding. Therefore the first step in evaluating impairment due to biostimulatory conditions is to determine whether existing nutrient loading and water column concentrations exceed background conditions. If it is determined that nutrient levels above background concentrations are present in the system then the CA NNE secondary endpoints are evaluated to determine whether they have exceeded the Beneficial Use Risk Category Level III boundary for impaired waters. It is when both background nutrient levels and CA NNE Level III indicator boundaries have been exceeded that a finding of impairment due to biostimulatory conditions can be supported.

Several sources within the Klamath and Lost River watersheds contribute to nutrient loading above background levels. Some of the key sources include irrigated agriculture return flows, internal nutrient cycling from nutrient enriched sediments, nutrients released as a result of wetland conversion, sediments from external sources derived from land disturbance activities, and to much lesser extent point sources. Without a comprehensive watershed inventory or model to estimate sediment / nutrient loading from diffuse sources, an alternative means is used to evaluate the status of nutrient conditions within the Klamath River. The analysis for this indicator is based on a comparison of estimated natural background water column concentrations of several nutrient species with existing conditions. Natural background conditions are estimated based on TMDL model simulations (described in Chapter 3). These estimates are not interpreted literally but

PRELIMINARY REVIEW DRAFT

only as approximations of conditions that may have existed previously. The existing conditions values come from the mean concentration of composite grab samples taken during the summer (June 1 to September 30) at twelve stations by various organizations from 1996 to 2007. Each station has at least three samples for each summer season over five years. Several stations have a much greater sampling density. The assumption for this analysis is that the annual and daily variability converges to an average over the course of a large number of samples that represent typical conditions during the summer growing season.

The purpose of the comparison is to evaluate whether nutrients have been increased by human related activities above the levels that could cause a nuisance, or adversely affect the water to support specified beneficial uses. This approach does not allow for any sort of mass balance comparison for the river since winter flows and concentrations have not been monitored. Rather, the estimates serve to provide a relative comparison of the mean summer concentrations of total nitrogen and total phosphorus to which aquatic life would be responding. Figures 2.9 and 2.10 illustrate the comparison of natural background with existing conditions. At most stations for both total phosphorous and total nitrogen the existing conditions concentrations exceed the natural background conditions. Frequently the existing conditions concentration is more than double the natural background conditions concentration. These results suggest through human activities that nutrient concentrations in the Klamath River are at a level that cause impairment to beneficial uses.

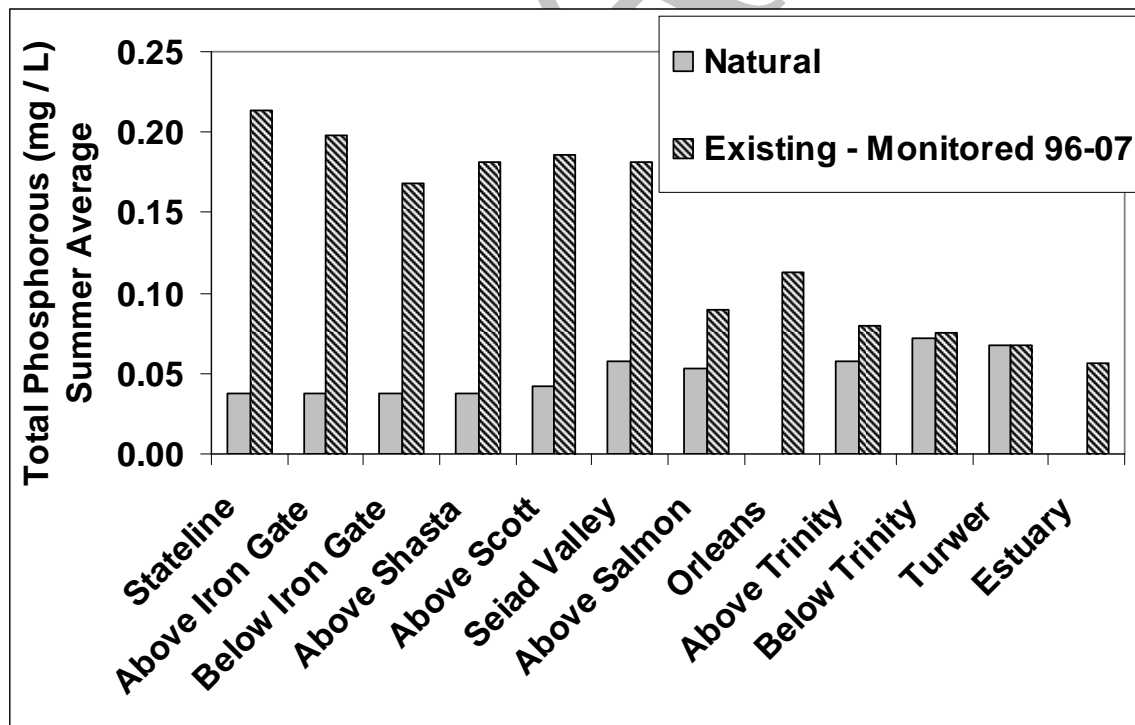


Figure 2.9: Comparison of total phosphorous summer means for estimated (TMDL model) natural background with existing (consolidated monitoring data 96-07)

PRELIMINARY REVIEW DRAFT

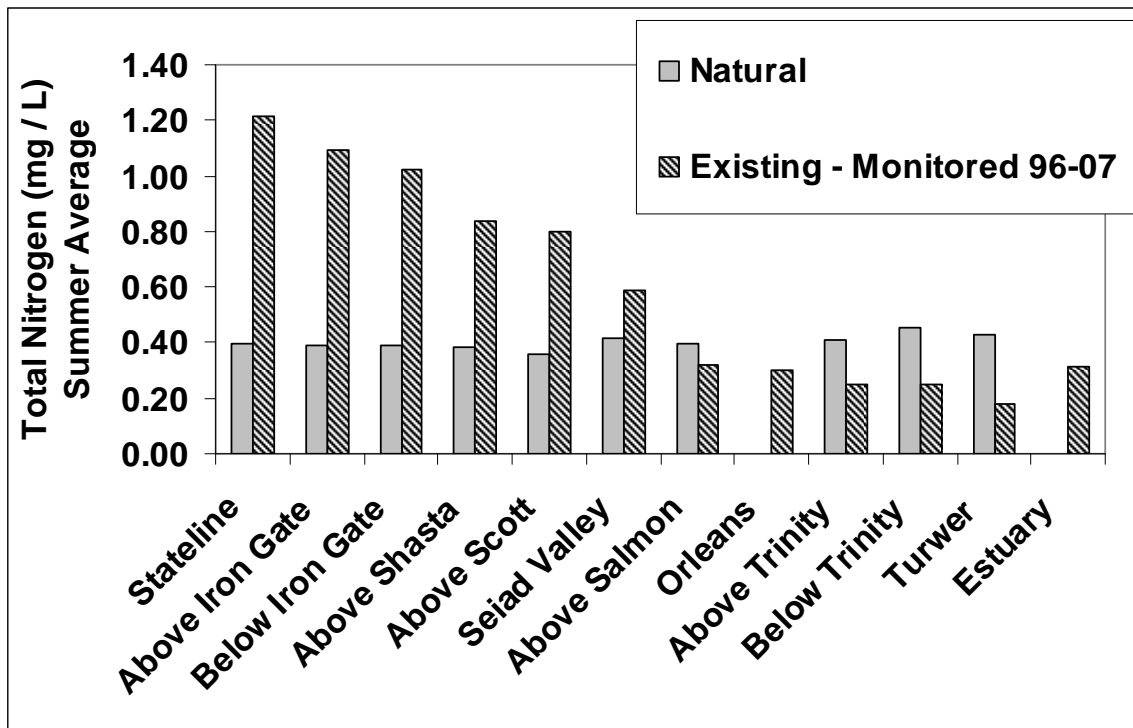


Figure 2.10: Comparison of total nitrogen summer means for estimated (TMDL model) natural background with existing (consolidated monitoring data 96-07)

2.4.3.2 Benthic Algal biomass

During the summer season dense mats of attached algae form on the rocky substrate of many reaches of the Klamath River. This vegetative mass is referred to variously in the literature as periphyton, macroalgae, macrophytes, and attached benthic algal biomass. For this assessment we have adopted the term benthic algal biomass. Because of the limited amount of periphyton data that has been collected in the Klamath River, California Regional Water Board staff used various lines of evidence to develop a target for this assessment. The lines of evidence include:

- The CA NNE algal biomass target for the boundary between Beneficial Use Risk Category II (potentially impaired) and III (presumptively impaired) for streams with a cold-water fishery use (COLD) was set at 150 mg chlorophyll-a / m². The CA NNE boundary target is based on a review of both regional and international studies and the recommendation of university and regional experts. The CA NNE also recommends the evaluation of other lines of evidence for each waterbody to ensure the appropriateness of this boundary condition. Because of the natural continuum of conditions from the Klamath headwaters (eutrophic) to its mouth (mesotrophic) the California Regional Water Board included other options for boundary condition determination.

PRELIMINARY REVIEW DRAFT

- The California Regional Water Board and EPA Region IX sponsored a CA NNE nutrient numeric endpoint analysis for the Klamath River in 2008 (Butcher 2008b). The study made use of the CA NNE scoping tools to assess benthic algal biomass targets under both existing conditions and natural background scenarios. The scoping tool provided very close estimates of existing benthic algal biomass using existing nutrient concentrations and information from other factors (e.g., accrual period). Using natural background concentrations at four locations along the mainstem Klamath (below Iron gate Dam) the scoping tool estimated an average benthic algal biomass density of 141 mg chlorophyll-a / m².
- The CA NNE the Hoopa Valley Tribe Basin Plan includes a criteria of 150 mg chlorophyll-a / m² for the reach of the Klamath River within the Hoopa Valley Indian Reservation.

Based on the three lines of evidence summarized above, California Regional Water Board staff will utilize a target of 150 mg chlorophyll-a / m² for this TMDL.

Figure 2.11 illustrates the results of the composited monitoring samples from events conducted in 2003, 2004, 2006, and 2007. There are a total of fifty samples for nine stations. The spatial and temporal sampling density is not ideal but does provide an objective measure of conditions that have been widely noted by those who have spent time on the Klamath River during the summer months.

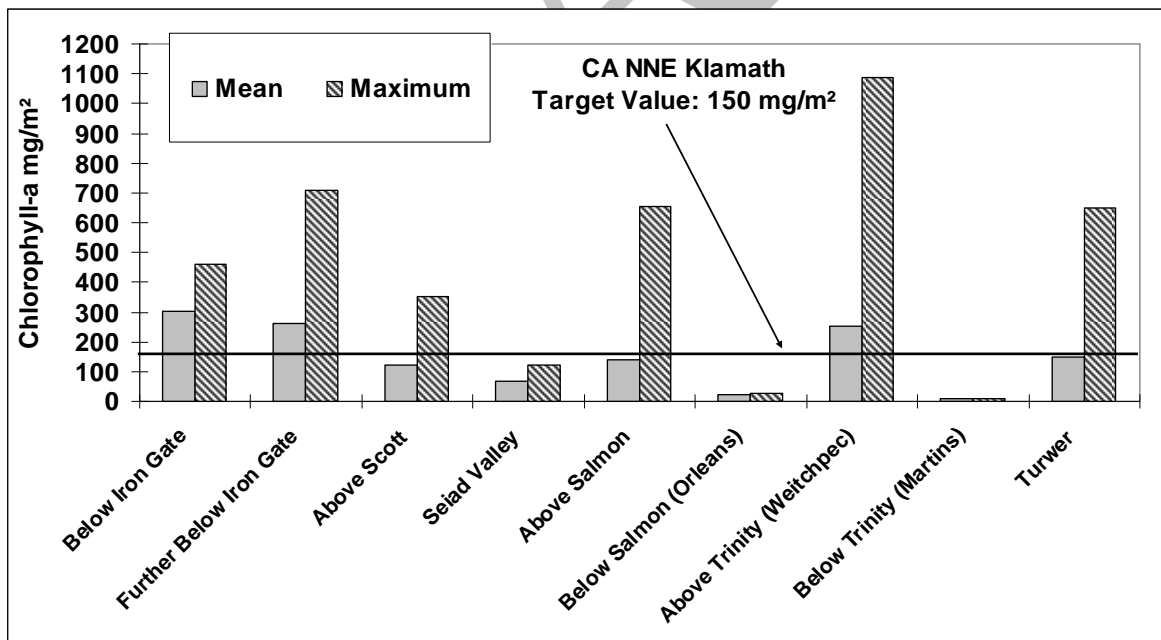


Figure 2.11: Benthic algal biomass consolidated monitoring results (summer mean and maximum) for 2003, 2004, 2006, and 2007 with CA NNE target (150 mg chlorophyll a / m²) and simulated background conditions

PRELIMINARY REVIEW DRAFT

Based on the limited available data, the mean algal biomass sample exceeds the Klamath River TMDL target and the Hoopa Valley Basin Plan criteria of 150 mg chlorophyll a / m² at four of nine stations. Thus, the Klamath River is impaired relative to benthic algal biomass density. As will be demonstrated in the following sections current condition algal biomass densities have direct negative water quality impacts. In addition to the water quality impacts demonstrated in the following sections the excess benthic algal biomass densities also provide habitat for polychaetes that serve as a host and source for the fish parasite *Ceratomyxa shasta*. Existing conditions for the benthic algal biomass indicator strongly suggests impairment.

2.4.3.3 Diurnal DO and pH

For several stations along the Klamath River the diurnal photosynthesis and respiration cycle is strongly influenced by dense colonies of benthic algal biomass which result in extreme diurnal cycles for DO and pH. The water quality conditions of frequent and chronic low DO and high pH illustrated in Figures 2.12 thru 2.14 creates chronic stressful conditions for resident fish populations. The illustrated plots are from 2006 at a single station, however the observed pattern is consistent with other time periods and other stations along the Klamath River. Both the existing DO objective (>8 mg / L) and pH objective (not grater than 8.5 and not less than 7.0) for the Klamath River downstream of Iron Gate Dam are exceeded on a regular basis. The extreme magnitude and regular frequency of these exceedences indicate impairment from biostimulatory substances (i.e., nutrients).

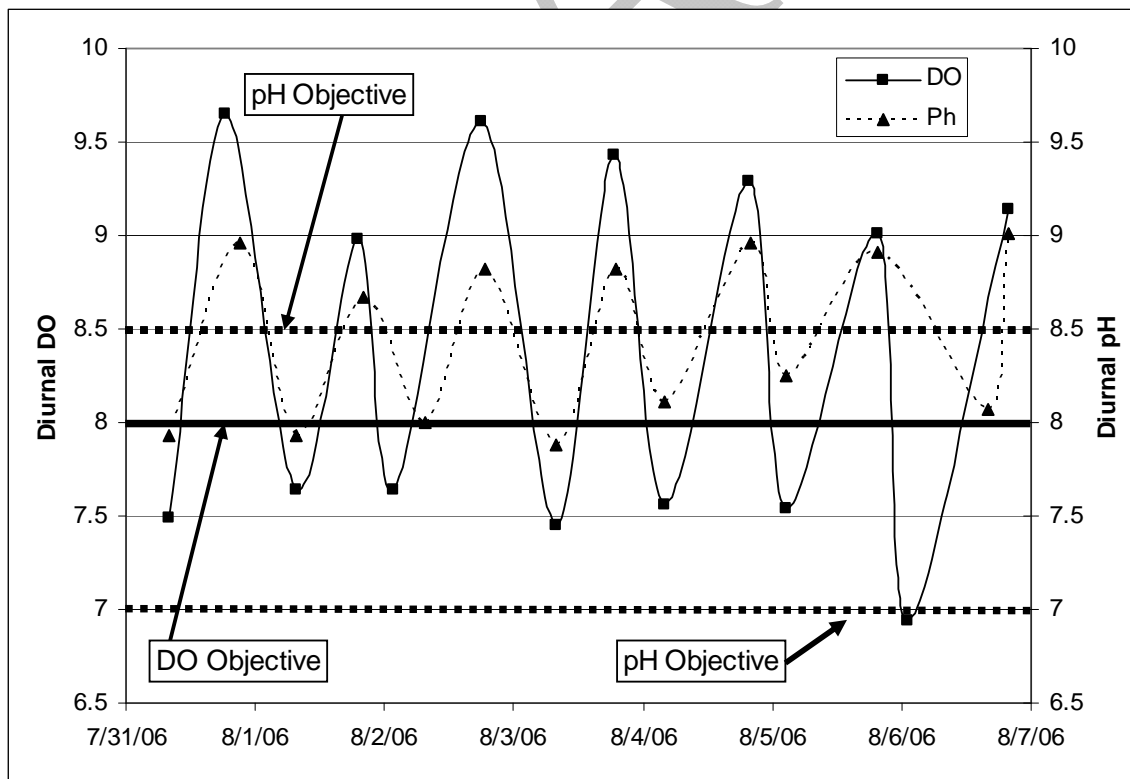


Figure 2.12: Example diurnal DO and pH cycle below Iron Gate Dam, summer 2006

PRELIMINARY REVIEW DRAFT

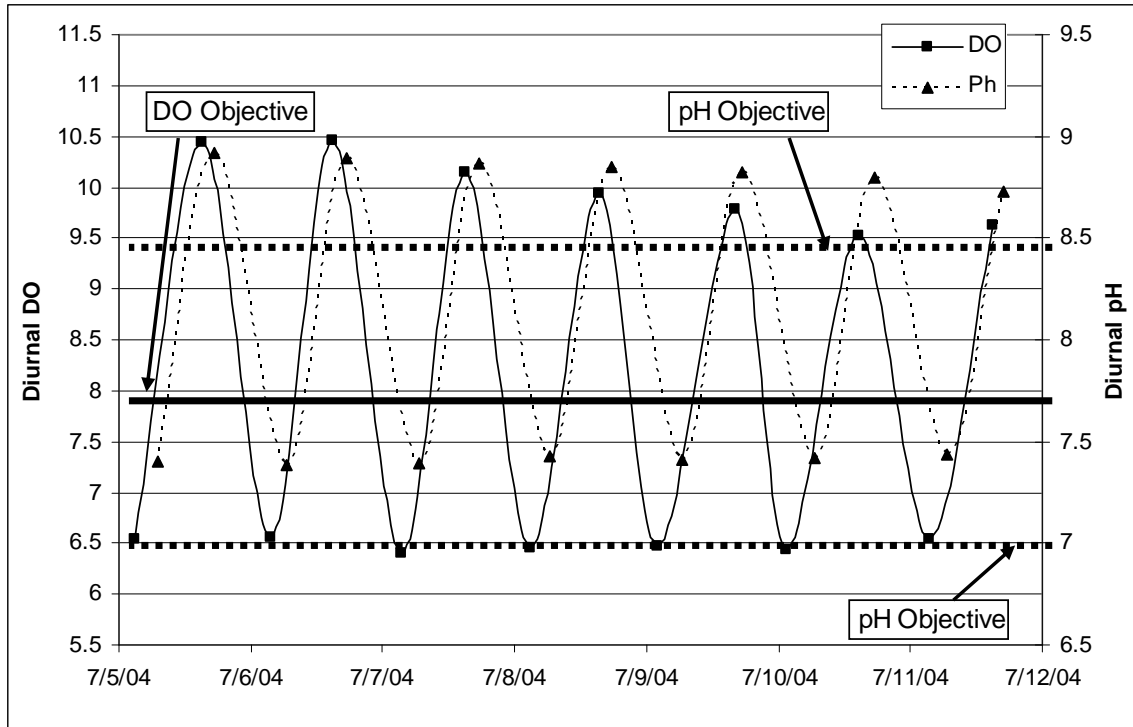


Figure 2.13: Example diurnal DO and pH cycle above the Shasta River, summer 2004

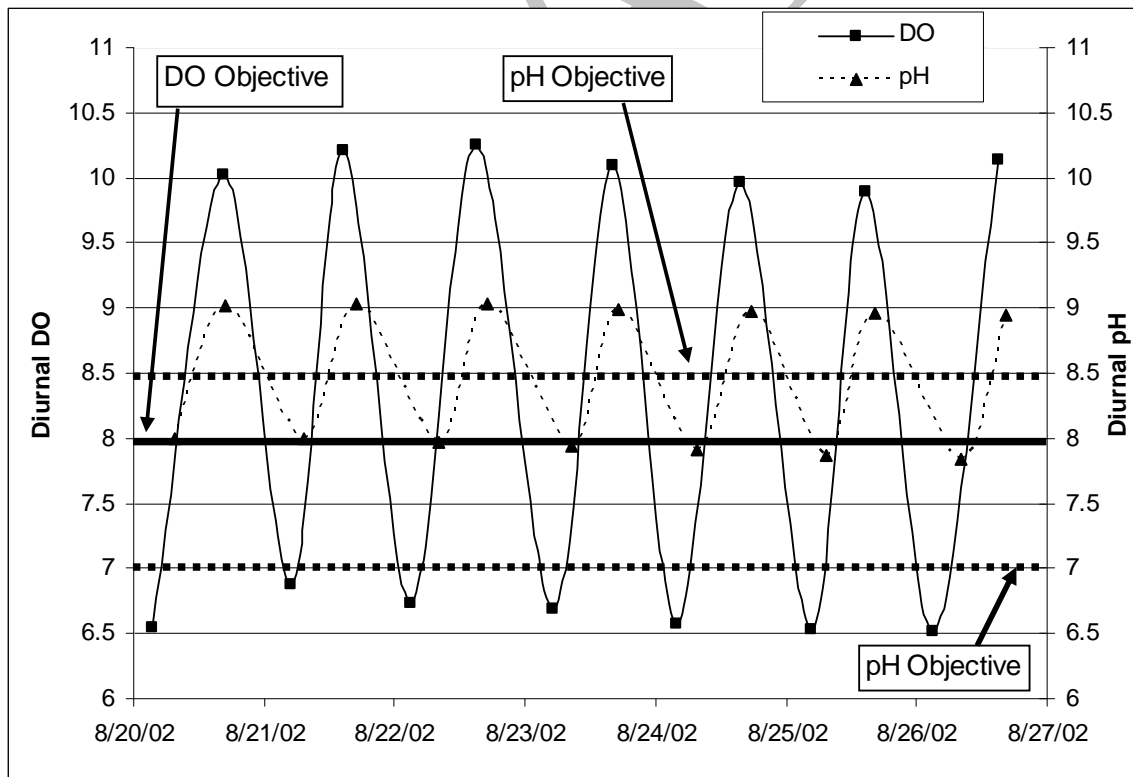


Figure 2.14: Example diurnal DO and pH cycle at Seiad Valley, summer 2002

PRELIMINARY REVIEW DRAFT

2.4.3.4 Chlorophyll-a – Reservoirs

Chlorophyll-a (chl-a) is an appropriate indicator for the Klamath River reservoirs. Chlorophyll-a concentrations of 10 µg / L were selected as the boundary between CA NNE framework Beneficial Use Risk Category II (potentially impaired) and Beneficial Use Risk Category III (presumptively impaired). This concentration was selected in part due to the rapidly increasing likelihood of nuisance algal blooms when chl-a concentrations are above the target concentration. There are frequent reports of nuisance algal blooms in Iron Gate and Copco Reservoirs. As illustrated in Figure 2.15 the summer mean concentrations of chlorophyll-a at all of the reporting stations for the reservoirs are at (1) or above (3) the summer mean target of 10 µg / L. The summer mean concentrations at three of the four stations are more than double the target. This productivity has impacts beyond water quality in the reservoirs. The outlet waters are rich with planktonic algae which is then available as a food source for polychaetes in river reaches below the dam (Wilzbach personal communication 2008). Another potential impact is that the reservoirs could be serving as a source for green and blue-green algae for the river reaches below the dams (Kann and Asarian 2005). The Iron Gate and Copco Reservoirs are thus considered to be impaired relative to the CA NNE chl-a indicator.

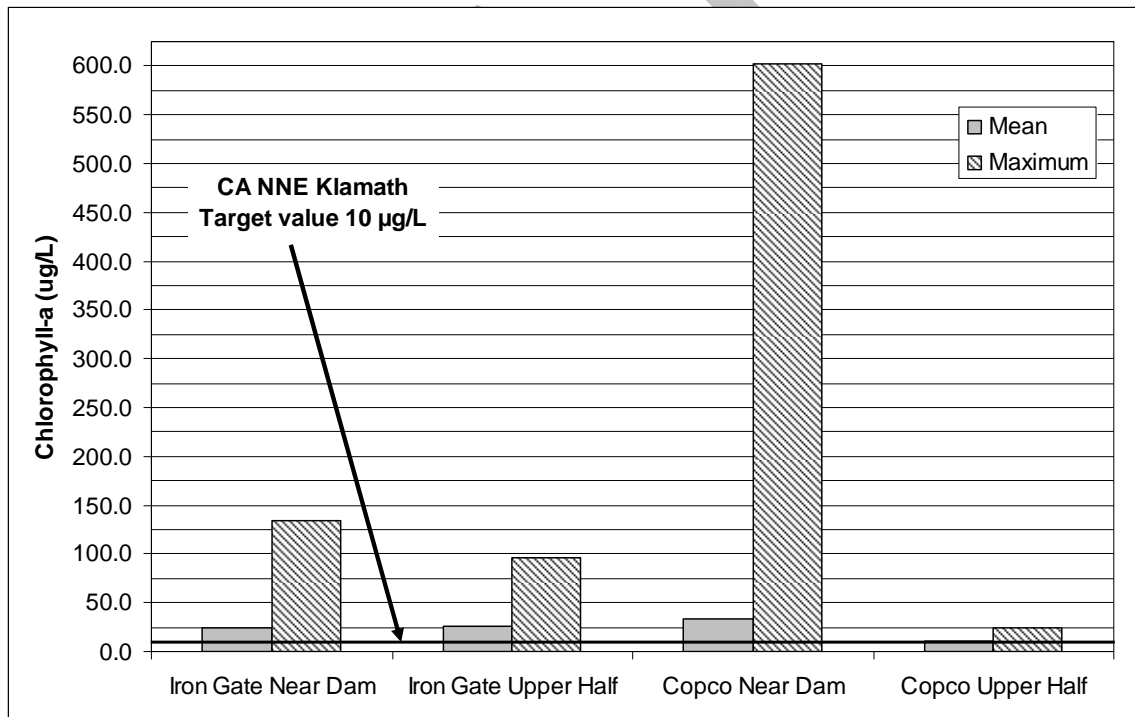


Figure 2.15: Summer mean concentrations of chlorophyll-a at four stations within the Iron Gate and Copco Reservoirs.

2.4.4 Blue-Green Algae and Microcystin Toxin

Another aspect of the nuisance algae conditions within Copco and Iron Gate Reservoirs is the periodic dominance of toxic blue-green algal species during the summer season. The blue-green algae assessment targets are described below.

PRELIMINARY REVIEW DRAFT

2.4.4.1 Guidelines for Algae and Blue-Green Algae in Freshwater

When health advisories are issued by agencies concerned that cyanotoxins are present in waterbodies at levels that may pose a health risk, they are often issued based on “guidelines” or “risk levels.” These guidelines are derived from analytic thresholds and field observations, and are established by the World Health Organization (WHO). The WHO guidelines are largely accepted by nations and territories world-wide (WHO 1999, p. 171-175; WHO 2003, pp. 149-154). The presence of extensive blue-green algal water discolorations and scum accumulations are often used as triggers to assess the relative health risk to humans and other organisms from possible cyanotoxin exposures.

The California Blue-Green Algae Work Group (California BGA Group), comprised of the California State Water Board, California Department of Public Health, and California Office of Environmental Health Hazard Assessment, have produced a guidance document (BGA Guidance) regarding recreational exposures to harmful algae blooms in fresh water titled *Cyanobacteria in California Recreational Water Bodies: Providing Voluntary Guidance about Harmful Algal Blooms, Their Monitoring, and Public Notification DRAFT* (California BGA Group 2008). The draft BGA Guidance presented in Table 2.9 utilizes the WHO guidelines and assigns health risk levels associated with recreational exposure to blue-green algae, including non-toxic and toxic byproducts.

Table 2.9: Guidelines for Algae and Blue-Green Algae in Fresh Water

Probability of adverse health effects	Guidance level or situation	How guidance level derived	Health Risks	Typical Actions ¹
Relatively low (LPAHEL)	20,000 blue-green algal cells/ml or 10 µg/ chlorophyll-a/liter with dominance of blue-green algae	From human bathing epidemiological study	Short-term adverse health outcomes, e.g., skin irritations, gastrointestinal illness.	Post on-site risk advisory signs Inform relevant authorities.
Moderate (MPAHEL)	100,000 blue-green algal cells/ml or 50 µg chlorophyll-a/liter with dominance of blue-green algae	Microcystin-LR ≥ 1 µg/L from provisional drinking-water guideline value for and data concerning other cyanotoxins	Potential for long-term illness with some blue-green algal species. Short-term adverse health outcomes, e.g., skin irritations, gastrointestinal illness.	Watch for scums or conditions conducive to scum formation. Discourage swimming and further investigate hazard. Post on-site risk advisory signs. Inform relevant authorities.
High (HPAHEL)	10,000,000 blue-green algal cells/ml Or Visible blue-green algal scum formation in areas where whole-body contact and/or risk of ingestion/aspiration occur	Inference from oral animal lethal poisonings Actual human illness case histories	Potential for acute poisoning. Potential for long-term illness with some blue-green algal species. Short-term adverse health outcomes, e.g., skin irritations, gastrointestinal illness.	Immediate action to control contact with scums. Possible prohibition of swimming and other water contact activities. Public health follow-up investigation. Inform public and relevant authorities.

Source: WHO 2003, Table 8.3 p.150 as cited by California BGA Group 2008

¹ Actual action taken should be determined in light of extent of use and public health assessment of hazard (California BGA Group 2008).

PRELIMINARY REVIEW DRAFT

Additionally, the BGA Guidance contains a decision tree, shown in Figure 2.16, which advises agencies, municipalities, Tribes, and other interested parties on when to post health alert notices. This figure presents threshold values at the decision nodes derived from the WHO guidelines (WHO 1999, 2003) and Oregon Department of Human Services (Oregon DHS) advisories for blue-green algae (Oregon DHS 2005). The WHO guideline for a Moderate Probability of Adverse Health Effects Level (MPAHEL) of 100,000 blue-green algal cells/ml is used in this decision tree. Additionally, two guidance values from Oregon DHS are utilized: 1) cell densities of *Microcystis* or *Planktothrix* $\geq 40,000$ cells/ml and 2) total microcystin toxin concentrations ≥ 8 ppb (1 ppb = 1 $\mu\text{g/L}$). Oregon DHS created guidelines using a risk assessment approach, stressing observations that almost all *Microcystis* strains are toxic, thus, lower concentrations of both constituents would be more protective of human health in recreational waters (Oregon DHS 2005).

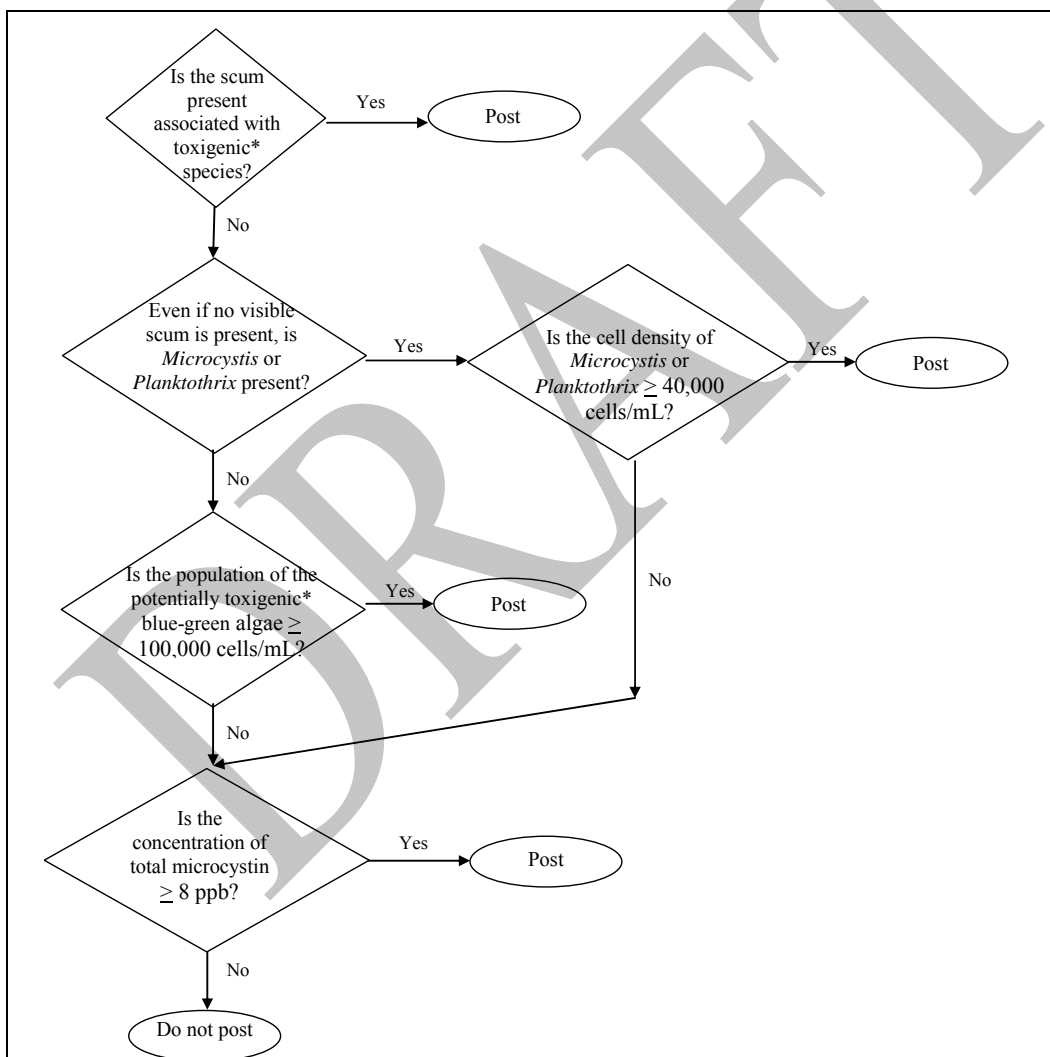


Figure 2.16: Decision Tree Advising When to Post Health Alert Notices Due to Blue-Green Algae and its Toxins

*Potentially toxic blue-green algae that have been detected in California include those of the genera *Anabaena*, *Microcystis*, *Aphanizomenon*, and *Gloeotrichia*. Additional blue-green algae that are known to be potentially toxic may be added to this list (California BGA Group 2008).

Source: California BGA Group 2008

PRELIMINARY REVIEW DRAFT

2.4.4.2 Summary of Blue-Green Algae and Microcystin Conditions

Historical Perspective - Pre-1990 Blue-Green Algae Conditions

Blue-green algae populations are known to have occurred in the Klamath River basin within Oregon and California for thousands of years (Eilers et al. 2001). References to blue-green algae were scientifically described as early as 1906 when J.B. Lippencot, Supervising Engineer for the Reclamation Service (now the Bureau of Reclamation), reported that the waters of Upper Klamath Lake "...are filled with some sort of organic matter, either animal or vegetable, so that they have a decidedly green appearance (Phinney and Peek 1960)." Phinney and Peek collected phytoplankton samples in Upper Klamath Lake that were later identified as containing three dominant genera of blue-green algae, *Anabaena sp.*, *Microcystis sp.*, and *Aphanizomenon sp.* These genera are still the dominant blue-green algae that periodically erupt into nuisance blooms within the Klamath River system.

1990 through 2004 Blue-Green Algae Conditions

From early 1990 through 2004 blue-green algae, including *Aphanizomenon flos-aquae* and *Microcystis aeruginosa*, were documented in samples collected by PacifiCorp as occurring downstream from Link River dam in Oregon through Copco and Iron Gate Reservoirs in California (PacifiCorp 2006). On September 29, 2004, analyses of samples collected at Copco Reservoir by Aquatic Ecosystem Sciences for the Karuk Tribe, showed that approximately 1.9 million cells/ml of *Microcystis* were quantified, which exceeded the WHO guidelines for a MPAHEL for recreational water use activities which is established at 100,000 cells/ml (Kann 2005; WHO 1999, p.171). The September 2004 data were associated with levels of the potent hepatotoxin, microcystin, at concentrations of 482 µg/L, which is above the California BGA Group action level of 8 µg/L for posting health advisories.

2005 Blue-Green Algae Conditions

On September 20, 2005, *Microcystis* and microcystin toxin levels in Copco Reservoir reached a maximum of approximately 163 million cells/ml and 1,994 µg/L, respectively, near the Copco Cove boat ramp. The *Microcystis* level exceeded the WHO guidelines for a MPAHEL by approximately 163 times and the microcystin level is above the California BGA Group action level of 8 µg/L for posting health advisories. *Microcystis* concentrations were somewhat lower in Iron Gate Reservoir, when on October 26, 2005 cell concentrations achieved a maximum of approximately 22.2 million cells/ml; however, microcystin toxin concentrations peaked in the reservoir a month earlier on August 25, 2005 when approximately 645 µg/L was reported (Kann 2005).

Excluding Copco and Iron Gate Reservoirs, analyses showed that on September 12, 2005 *Microcystis* and microcystin toxin concentrations in the Klamath mainstem below Link River dam exceeded the WHO guidelines of a MPAHEL at only one site, a backwater pool at the Coon Creek Recreational Access along the Klamath River. *Microcystis* and microcystin was also detected at a number of other locations in the mainstem below Link River dam but their concentrations did not exceed health advisory thresholds. In addition to *Microcystis aeruginosa*, a population bloom of the neurotoxin producing blue-green

PRELIMINARY REVIEW DRAFT

algae, *Anabaena flos-aquae*, occurred between Link River Dam and Copco Reservoir during 2005, and was also found at low levels in samples collected in Iron Gate Reservoir in 2006 and 2007 (Fetcho 2006; Kann and Corum 2006).

2006 Blue-Green Algae Conditions

Maximum *Microcystis* concentrations in Copco and Iron Gate Reservoirs measured in 2006 are summarized in Figure 2.17, and 2006 maximum microcystin concentrations in the mainstem Klamath River are presented in Figure 2.18. During 2006 trends in the concentrations of both *Microcystis* and microcystin exceeded those of past sampling events, particularly in Copco Reservoir. Analyses of water samples collected in the reservoir on July 27, 2006 showed seasonally maximum levels of *Microcystis* at 393 million cells/ml, and microcystin toxin at 2,813 µg/L (Kann 2006); concentrations which were well in excess of the WHO guidelines for a MPAHEL and the California BGA Group action level of 8 µg/L for posting health advisories.

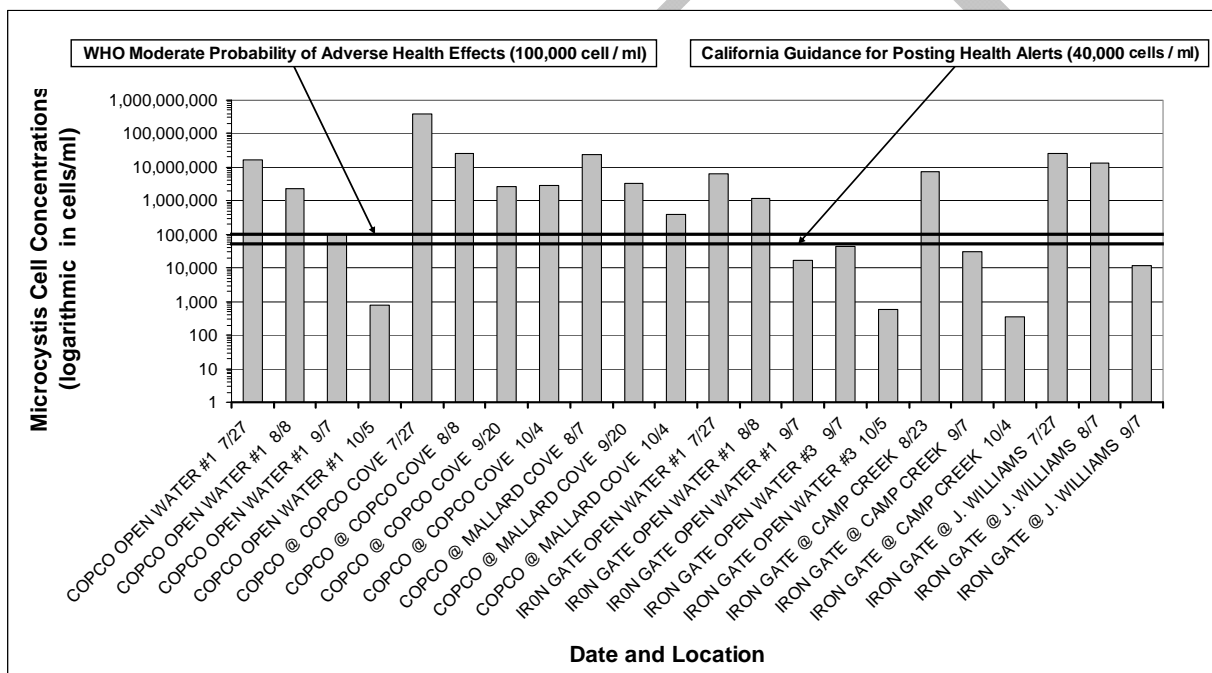


Figure 2.17: Maximum *Microcystis* cell concentrations for summer 2006 at stations within Iron Gate and Copco Reservoirs

In the mainstem Klamath River, the highest density of *Microcystis* was found at Seiad Valley on August 23, 2006. The *Microcystis* concentration was measured as 41,229 cells/ml (Fetcho 2007a), which exceeded the California BGA Group action level of 40,000 cells/mls for posting health advisories. A maximum microcystin toxin concentration of 9.2 µg/ml was measured at a sample site immediately below Iron Gate dam on August 23, 2006 (Fetcho 2007a). This result is above the California BGA Group action level of 8 µg/l for posting health advisories.

PRELIMINARY REVIEW DRAFT

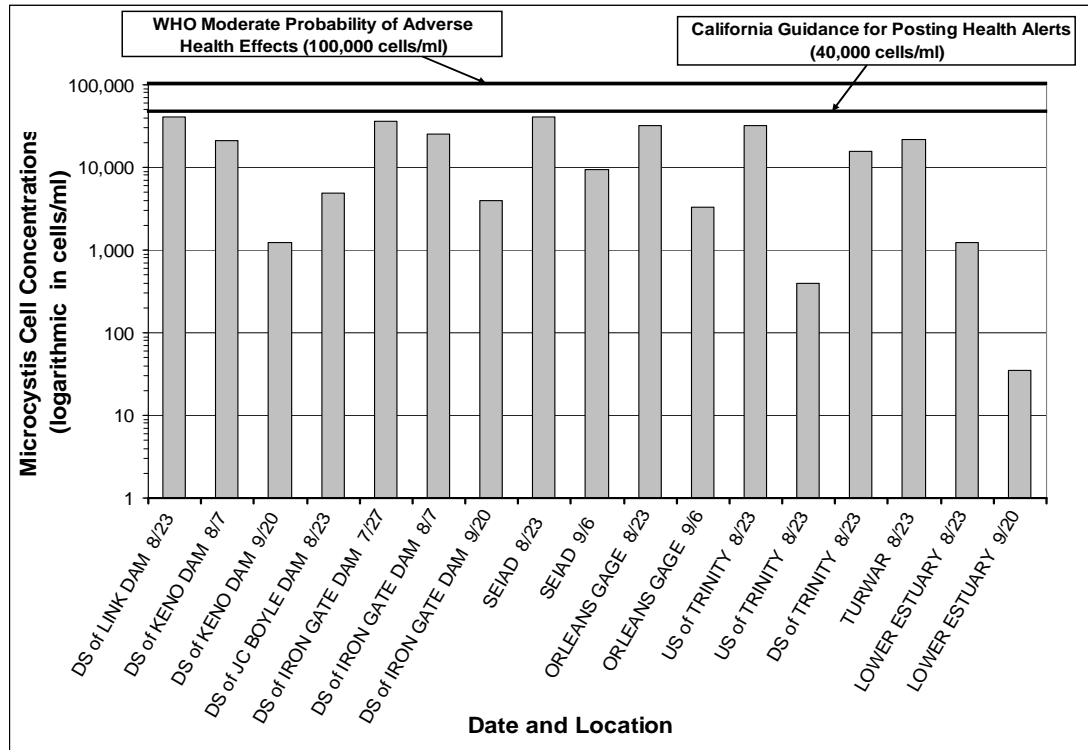


Figure 2.18: Maximum microcystin toxin concentrations for summer 2006 at stations along the mainstem of the Klamath River

2007 Blue-Green Algae Sampling Conditions

Maximum *Microcystis* concentrations in Copco and Iron Gate Reservoirs measured in 2007 are summarized in Figure 2.19, and 2007 maximum microcystin concentrations in the mainstem Klamath River are presented in Figure 2.20. During the early summer sampling season of 2007, field collections and laboratory results indicated that the presence of large concentrations of *Microcystis* occurred beginning in late May and early June in Copco and Iron Gate Reservoirs, approximately one month earlier than 2005 and 2006 (Corum 2007a). *Microcystis* scums were also present from mid- to late June 2007.

Laboratory results show that maximum cell counts for *Microcystis* in Iron Gate Reservoir near the dam reached approximately 15,285,884 cells/ml on October 4, 2007, and a maximum *Microcystis* concentration of 22,898,635 cells/ml was measured in Copco Reservoir at Copco Cove on September 5, 2007 (Kann 2007). Both of these values greatly exceed the WHO guidelines for a MPAHEL and the California BGA Group action level of 40,000 cells/mls for posting health advisories

Maximum microcystin toxin concentration in Iron Gate Reservoir peaked on June 27, 2007 measuring 1,100 µg/L (Kann 2007), a level that is approximately 138 times above the California BGA Group guidance level for posting health alerts of 8 µg/L. Microcystin concentrations in Copco Reservoir reached a maximum of 30,000 µg/L on

PRELIMINARY REVIEW DRAFT

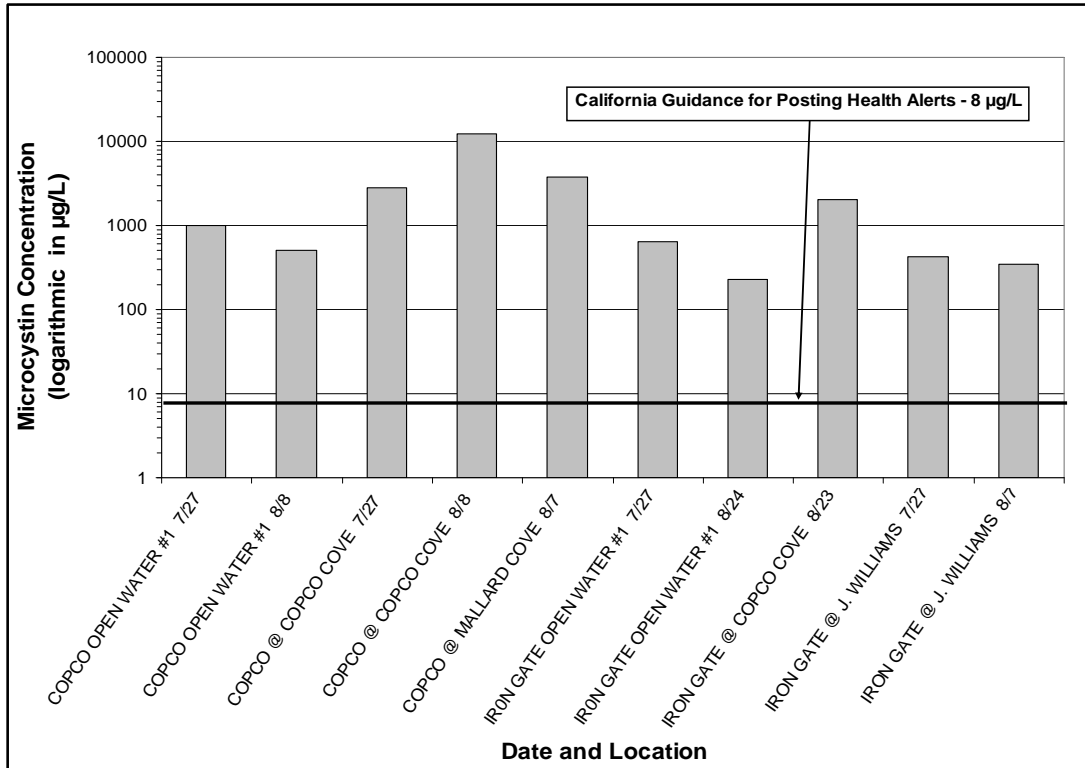


Figure 2.19: Maximum Microcystin Toxin for Summer 2007 in Iron Gate and Copco Reservoirs

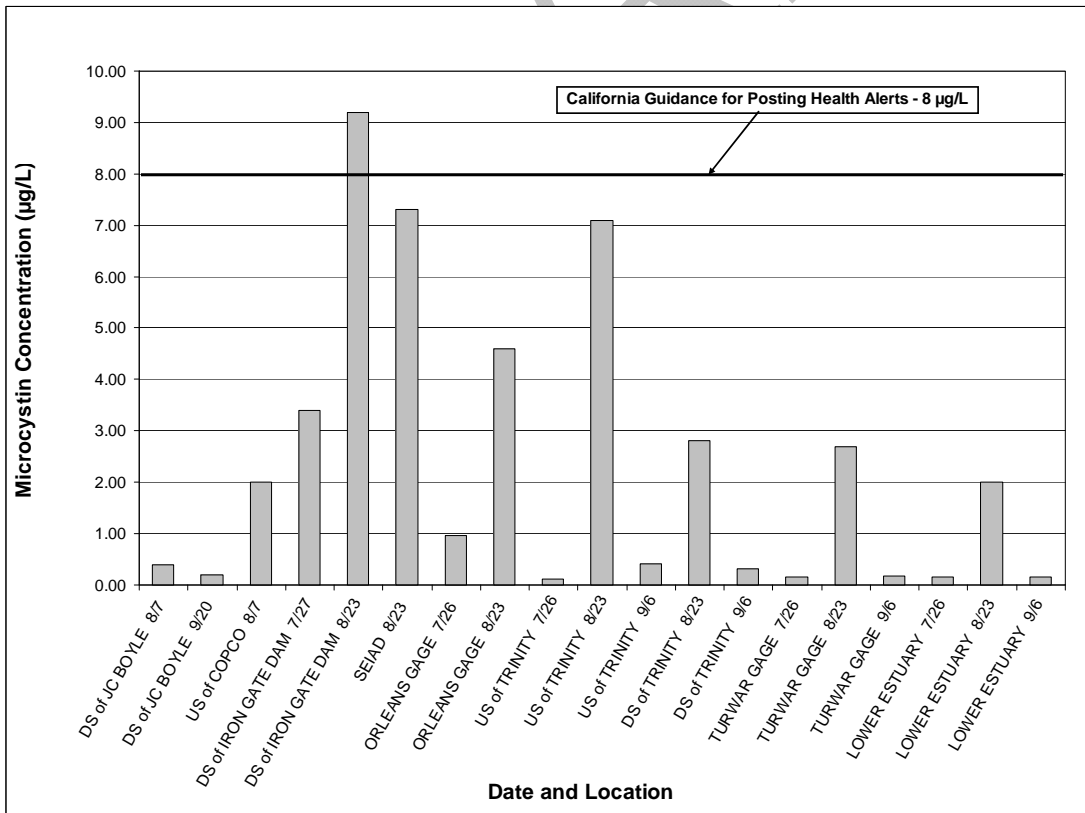


Figure 2.20: Maximum *Microcystis* cell concentrations for summer 2007 at stations along the mainstem of the Klamath River.

PRELIMINARY REVIEW DRAFT

August 21, 2007 (Kann 2007), a result that is approximately 3,750 times above the State Water Board guidance level 8 µg/L(2007) for posting health alerts.

In the mainstem Klamath River, maximum *Microcystis* concentrations were detected in the lower estuary at levels of 90,764 cells/ml on September 18, 2007 (Fetcho 2007b), a level that is approximately 2.3 times above the State Water Board's guidance of 40,000 cells/ml for posting health alerts at waterbodies containing *Microcystis aeruginosa* and/or *Planktothrix* sp.

2.4.5 Dissolved Oxygen

The DO indicator is somewhat different than the diurnal DO and pH indicator discussed in Section 2.4.3.3. The diurnal indicator discussed is used to evaluate biostimulatory conditions via a linkage with benthic algal biomass. The DO indicator evaluated in this section is the existing and proposed Basin Plan water quality objective.

The US Fish and Wildlife Service (USFWS), in cooperation with the Karuk and Yurok Tribes, monitored DO conditions with datasondes at several stations along the Klamath River from 2001 to 2006. For the purposes of this assessment measured DO concentrations from the three most recent years (2004 – 2006) are evaluated in comparison to the existing and proposed DO objective. USFWS conducted an in-depth quality control review of the DO data (Armstrong and Ward 2008). The corrected datasonde results have been summarized by station by evaluating the percent of total measurements during the summer season that fall below the current Basin Plan DO Objective of 8.0 mg/L. The datasondes recorded water quality conditions at 30-minute increments, for a total of forty-eight daily measurements.

Greater than ten percent of the DO measurements are less than 8.0 mg/L at six of the nine stations along the Klamath River (Table 2.10 and Figure 2.21). At four stations (below Iron Gate, above Shasta River, above Scott River, and at Seiad Valley) more than 40% of the measurements are less than the current Basin Plan objective.

Table 2.10: Percent of DO measurements below Basin Plan Water Quality Objective of 8.0 mg/L for 2004 – 2006 at nine stations along the Klamath River

% Measurements below 8 mg/l	2004		2005		2006	
	n	%	n	%	n	%
At Iron Gate	2706	64	4498	45	5391	61
Above Shasta River	5478	50	5533	49	-	-
Above Scott River	2966	58	4457	47	-	-
At Seiad Valley	3381	57	4713	45	5526	40
At Orleans	4057	37	4533	23	5349	15
Above Trinity	-	-	5535	5	5739	3
At Weitchpec	4142	48	5400	7	5332	6
Below Weitchpec	5500	16	3529	11	5293	4
At / above Turwar	5066	30	5543	6	-	-

PRELIMINARY REVIEW DRAFT

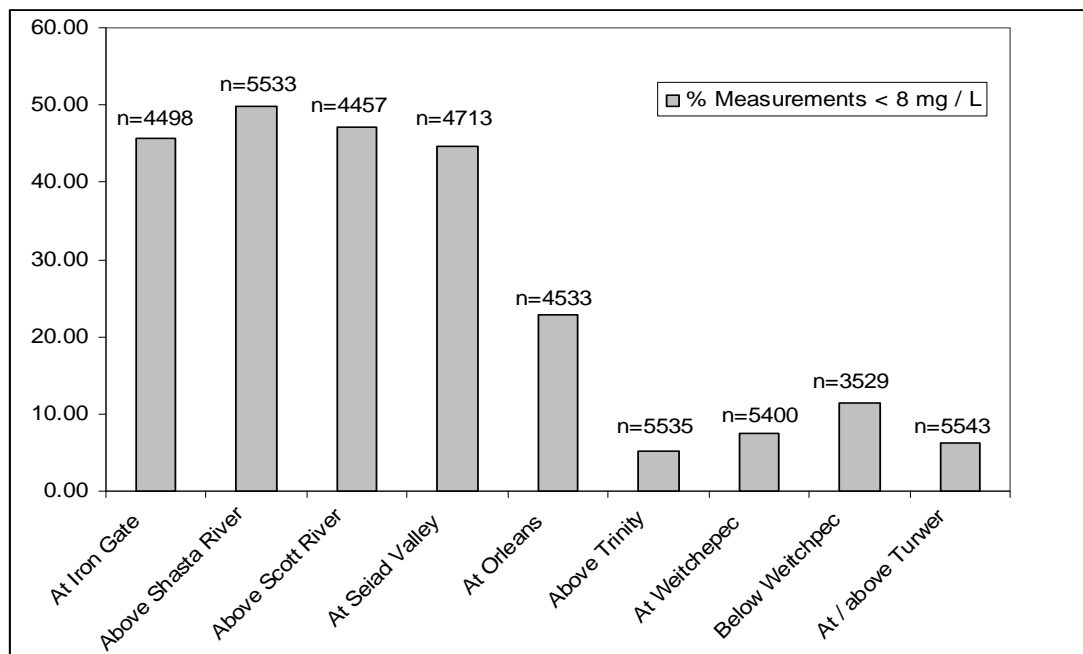


Figure 2.21: Percent of DO measurements below Basin Plan Water Quality Objective of 8.0 mg/L for 2005 at nine stations along the Klamath River

The analysis presented below addresses the revised DO objective being proposed. The revised objective requires that in those waterbodies identified as COLD but unable to meet the salmonid life cycle requirements due to natural conditions, a minimum 85% saturation limit, as calculated based on natural water temperatures must be maintained.

In order to compare the USFWS measured DO data to the proposed DO objective assumptions related to temperature and barometric pressure were made. Percent DO saturation was calculated based on measured water temperatures and using a seasonal average barometric pressure. These assumptions make for a very conservative estimate of the percent of measurements below the proposed objective of 85% DO saturation at natural water temperatures. Natural water temperatures for the years 2004-2006 are not known as the TMDL model has not been applied to these years. The results of the analysis are presented in Table 2.11 and Figure 2.22. In 2004, six of the nine stations had more than 10% of the DO measurements below 85% DO saturation.

Table 2.11: Percent of calculated percent DO saturation estimates below the proposed Basin Plan Water Quality Objective of 85% saturation for 2004 – 2006 at nine stations along the Klamath River

% Measurements below 85% saturation at median of pressure range	2004		2005		2006	
	n	%	n	%	n	%
At Iron Gate	2706	10	4498	6	5391	18
Above Shasta River	5478	25	5533	24	-	-
Above Scott River	2966	35	4457	20	-	-
At Seiad Valley	3381	14	4713	11	5526	0
At Orleans	4057	6	4533	0	5349	0
Above Trinity	-	-	5535	0	5739	0
At Weitchpec	4142	19	5400	0	5332	0
Below Weitchpec	5500	0.1	3529	0	5293	0
At / above Turwar	5066	12	5543	0	-	-

PRELIMINARY REVIEW DRAFT

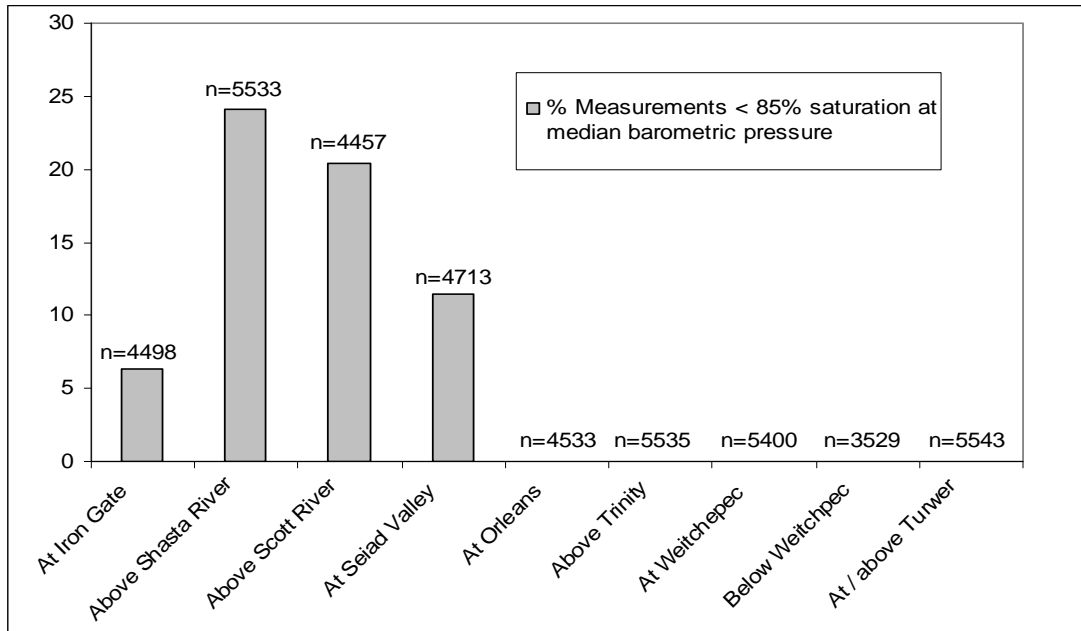


Figure 2.22: Calculated percent DO saturation at nine stations on the Klamath River for 2005

2.4.6 pH

This assessment includes an evaluation of pH conditions along the Klamath River independent of the diurnal variation driven by photosynthesis that was addressed in Section 2.4.3.3. The data for this analysis also comes from the USFWS, Karuk and Yurok Tribes datasonde measurements. The same years (2004 – 2006) used in the DO analysis were also selected for the pH assessment. The Basin Plan water quality objective for pH is a maximum of 8.5 and a minimum of 7.0.

For 2005 (Figure 2.23) at six of the nine Klamath River stations the Basin Plan objective of 8.5 is exceeded in more than 15% of the samples taken.

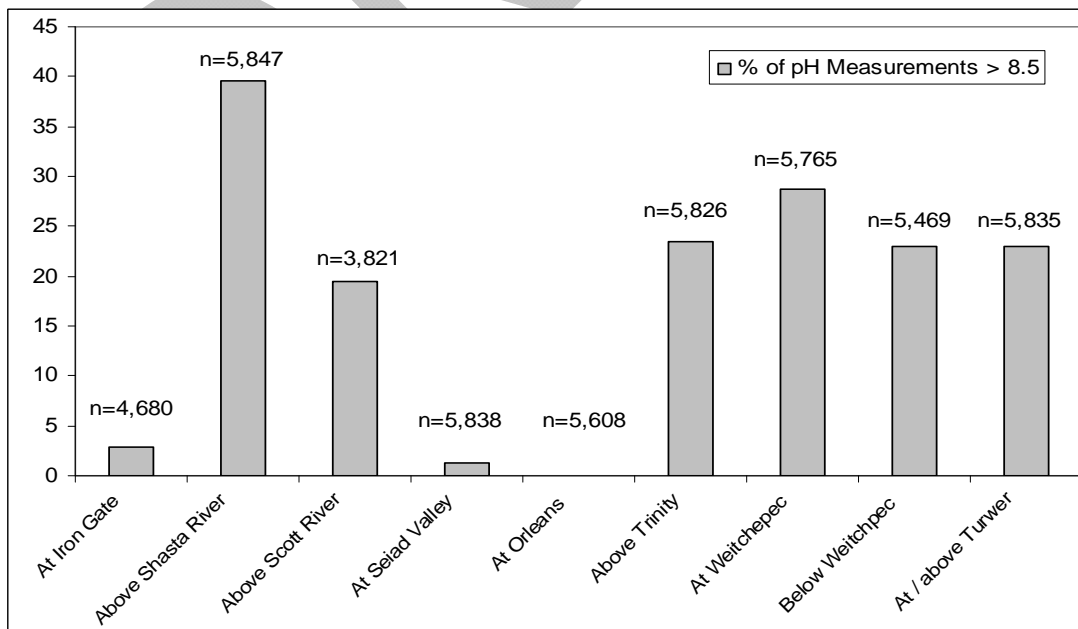


Figure 2.23: Percent of 2005 pH measurements in the Klamath River that exceed 8.5

PRELIMINARY REVIEW DRAFT

Five of the stations have more than 20% noncompliant measurements. The highest rate of noncompliant measurements is 48% recorded at Orleans in 2006 (Table 2.12). In the three year sample all nine stations exceeded a noncompliant measurement rate of greater than 10 percent at least once. The rate of noncompliance for the minimum pH of 7.0 is less than 0.05% at all stations. Therefore a sampling station summary table and plot have not been prepared for minimum pH.

Table 2.12: Percent of pH measurements above 8.5 for 2004 – 2006 at nine stations along the Klamath River.

Percent of Measurements above 8.5	2004		2005		2006	
	n	%	n	%	n	%
At Iron Gate	5192	32	4680	3	5486	30
Above Shasta River	5762	37	5847	40	-	-
Above Scott River	3834	28	3821	19	-	-
At Seiad Valley	3808	1	5838	1	5576	32
At Orleans	4844	0	5608	0	5442	48
Above Trinity	-	-	5826	23	5746	18
At Weitchpec	4449	33	5765	29	5823	27
Below Weitchpec	5823	1	5469	23	5125	42
At / above Turwar	4712	16	5835	23	-	-

2.4.7 Ammonia Toxicity

California Regional Water Board staff evaluated all the data within our compiled Klamath River datasets in which all 3 parameters (pH, NH₃, and temperature) were collected at the same time. Based upon the evaluation, there were no documented times in which acute or chronic aquatic life criteria for ammonia toxicity was exceeded.

To take this one step further, staff evaluated all the available pH and temperature data to determine what the concentration of ammonia would need to be in order for toxicity (acute or chronic) to be present. The results of that effort showed that acute toxicity probably does not occur on the Klamath River in California. However, the results showed that there are probably times when the chronic criteria are exceeded, but only for short durations of perhaps a few hours in a day on a few days in a year. California Regional Water Board staff concludes that based on the available data, acute ammonia toxicity has not occurred in the times/years when data is available, and chronic ammonia toxicity probably only occurs for short durations on a few days in a year.

2.4.8 Sediment

The New Years Day flood of 1997 provided an example of some of the ways in which increased sediment loads affect stream temperatures in the Klamath River basin. A report by Klamath National Forest personnel (De La Fuente and Elder, 1998) documenting the flood impacts within the Klamath national Forest reported 536 miles (19%) of channels that were significantly altered (i.e. with significant scouring, excessive sediment deposition, or riparian vegetation removal) by the flooding and associated sediment pulses of the 1997 flood. The report stated that “there appeared to be a considerable reduction in size, volume, and depth of pools in Elk, Indian, Beaver,

PRELIMINARY REVIEW DRAFT

Grider, Tompkins, South Fork Salmon, and Walker Creeks, and there is a larger proportion of fine sediment in the substrate. Alluvial reaches were made shallower and wider due to the sedimentation”. The report found that approximately 30% to 60% of riparian vegetation was lost in the alluvial reaches of the most affected tributaries. These effects of increased sediment loads were observed in Elk, Indian, Ukonom, Independence, Grider, Oneil, Portuguese, Beaver, Horse, and Walker Creeks, as well as numerous other streams throughout the Klamath basin after the flood of 1997 (Figure 2.24 (De La Fuente and Elder 1998; Kier Associates 1999).

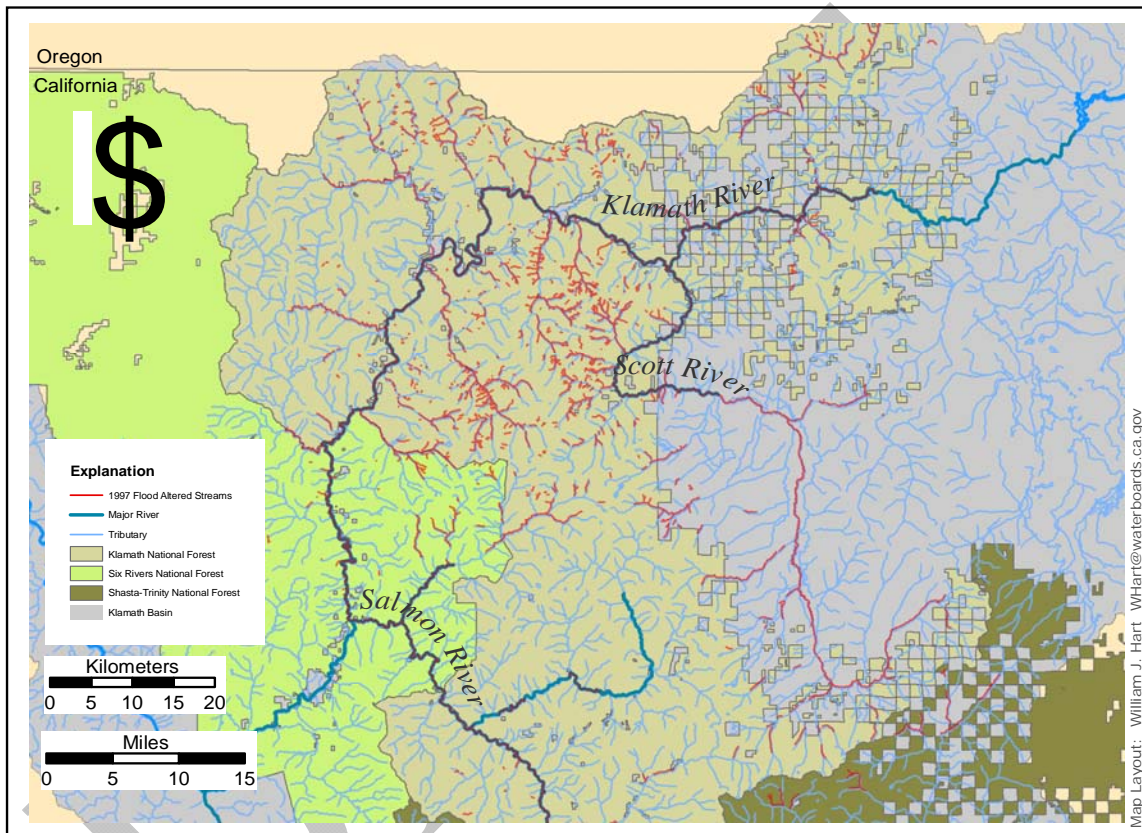


Figure 2.24: Mapped extent of stream channels substantially altered by sediment loads associated with the 1997 flood. Source: Klamath National Forest.

De la Fuente and Elder presented a comparison of Elk Creek temperature data before and after the flood. The data showed that in the summer after the flood, the peak temperature was the highest of seven years of record, and was 3.8°F higher than the average from 1990-1995. Likewise, the diurnal variation increased to 12.5°F, 4.9°F higher than the 1990-1995 average.

2.5 Evidence of Beneficial Use Impairment

Section 2.4 demonstrates that temperature, DO, biostimulatory substances, and related water quality objectives are not met at many locations at some times of the year in the Klamath River in California. Exceedance of these water quality objectives contributes to the impairment of a number of existing beneficial uses in the Klamath River. Evidence

PRELIMINARY REVIEW DRAFT

of impairment of the COLD, RARE, MIGR, SPWN, CUL, FISH, REC-1, REC-2, and MUN beneficial uses is presented in this section. This evidence of beneficial use impairment compels the need to develop TMDLs to address the temperature, DO, and nutrient water quality problems in the Klamath River.

2.5.1 Evidence of Impairment to Cold Freshwater Habitat (COLD), Rare, Threatened, or Endangered Species (RARE), Migration of Aquatic Organisms (MIGR), and Spawning, Reproduction, and/or Early Development (SPWN)

The COLD, RARE, MIGR, and SPWN beneficial uses are currently not fully supported in the Klamath River in California, as demonstrated by the decline of salmonid populations, adult and juvenile fish kills caused by disease outbreaks, migration barriers for adult and juvenile salmonids, and degradation of spawning habitat.

2.5.1.1 Salmonid Population Decline

Although historically there were large runs of salmonids in the Klamath River basin, current data indicate that populations have declined sharply since the early 1900's. Utilizing information from Snyder (1931), the National Research Council of the National Academies (NRC) estimated that the annual total catch in the Klamath River during the period from 1916-1927 was probably 120,000 to 250,000 fish, and thus the number of potential spawners and total population numbers was considerably higher (NRC 2004, p.267, 268). In 2007, fall and spring Chinook population estimates were 132,167 and 12,628 respectively (CDFG 2008). No current estimate of steelhead and coho populations has been made, however, it is presumed that populations have declined dramatically from historic numbers (Brown and Moyle 1991, p.8; Brown et al. 1994; Busby et al. 1994 as cited by NRC 2004, p.274; CDFG 2002, p.1; NRC 2004, p.273). More detailed information on the decline of salmonid populations in the Klamath River basin can be found in Appendix 2, and brief summaries are presented below.

Fall Chinook Salmon

Fall Chinook numbers in the Klamath River basin have dramatically declined during the past century (Hardy and Addley 2006, p.7). The Klamath River fall Chinook run once totaled as many as 500,000 fish annually (Moyle 2002, p.258). Fall Chinook numbers in the Shasta River basin alone, historically numbered 20,000-80,000 fish per year (NCRWQCB 2006, p.1-25). Basin-wide fall Chinook population estimates for the period from 1978-2007 ranged from a high of 239,559 fish in 1987 to fewer than 35,000 fish in 1991 (CDFG 2008).

Spring Chinook Salmon

A population of more than 100,000 spring-run Chinook was once present in the basin, although this estimate is probably low because spring-run fish were the main run of Chinook in the Klamath mainstem in the 1800's (Moyle 2002, p.259). Historic run size estimates in each of the Sprague River, Williamson River, Shasta River, and Scott River alone were at least 5,000 fish (CDFG 1990 as cited by Moyle 2002, p.259). Population estimates for spring Chinook during the period from 1980-2006 ranged from a high of 69,004 fish in 1988 to fewer than 1,945 in 1983 (CDFG 2006).

PRELIMINARY REVIEW DRAFT

Steelhead Trout

Hardy and Addley (2006, p.6) report that historical run sizes for steelhead trout in the Klamath River basin were estimated at 400,000 fish in 1960 (USFWS 1960 as cited by Leidy and Leidy 1984), 250,000 in 1967 (Coots 1967), 241,000 in 1972 (Coots 1972) and 135,000 in 1977 (Boydston 1977). More recent run sizes are summarized below.

Spring/Summer Steelhead Trout

Annual counts of spring/summer steelhead in holding areas throughout the Klamath River basin ranged from 500 to 3,000 fish (Roeloffs 1983, as cited by Hopelain 1998, p.1). In the 1990's it was estimated that there were 1000-1500 spring/summer steelhead adults divided among eight populations in the basin (Barnhart 1994; Moyle et al. 1995; Moyle 2002 as cited by NRC 2004, p.274). NMFS considers spring/summer steelhead stocks depressed and in danger of extinction (Busby et al. 1994 as cited by NRC 2004, p.274).

Fall Steelhead Trout

The fall steelhead represent the largest of the three steelhead runs, and were estimated to include 55,000-75,000 spawning adults and 150,000-225,000 half-pounders during the period from 1980-1982 (D.P. Lee, CDFG, pers. comm. as cited by Hopelain 1998, p.1).

Winter Steelhead Trout

Run size estimates for Klamath River winter steelhead were 170,000 in the 1960s, 129,000 in the 1970s, and 100,000 in the 1980s (Busby et al. 1994 as cited by NRC 2004, p.273). Current population estimates for winter steelhead have not been conducted, although Hopelain (1998, p.1) estimated a run-size of about 5,000 to 25,000 during 1980-1982. It is presumed that winter steelhead abundance is still declining although estimates, both past and present, are not very reliable (NRC 2004, p.273).

Coho Salmon

It is clear from the information available that coho salmon populations statewide have undergone a dramatic decline from historic levels (Brown and Moyle 1991, p.8; Brown et al. 1994; CDFG 2002, p.1). Maximum estimates for coho spawners in California during the 1940's range from 200,000-500,000 fish (Sagar and Glova 1988 as cited by Moyle 2002, p.250). Brown et al. (1994) state that California coho populations are probably less than 6% of what they were in the 1940s, and there has been at least a 70% decline since the 1960s. In 1994, Brown et al. estimated the coho salmon population in California to be 30,000 fish, with natural spawners comprising 43% of the total population or 13,240 fish.

The Southern Oregon/Northern California Coast Evolutionary Significant Unit (SONCC ESU), which encompasses Klamath River stocks, has been listed as threatened by the State of California and the Federal government. Coho salmon occupy only 61% of the SONCC ESU streams previously identified as historical coho salmon streams (CDFG 2002, p.2).

PRELIMINARY REVIEW DRAFT

Historical spawning escapement estimates for the Klamath River basin approximate 15,400-20,000 coho, with 8,000 of these fish originating in the Trinity River (USFWS 1979, App. as cited by Brown et al. 1994). In 1965, CDFG estimated 15,400 coho spawners per year in the basin (CDFG 1965, p.369). In 1994, Brown et al. estimated a total abundance of 18,125 coho in the Klamath River, including 1,860 native and naturalized fish. Current population estimates for coho in the Klamath River basin have not been conducted, although adult coho return numbers to the Iron Gate Hatchery, Trinity River Hatchery, and Shasta River Fish Counting Facility during the last 42 years averaged 5949 fish (Hampton 2004, p.1; Hampton 2005a, p.1; Hampton 2005b; KRIS 2006; Marshall 2005; and Rushton 2005).

2.5.1.2 Juvenile and Adult Fish Kills

Poor water quality conditions in the Klamath River have resulted in both adult and juvenile fish kills reflecting an impairment of the COLD and RARE beneficial uses. Figure 2.25 identifies the mainstem Klamath River reaches in California where adult and juvenile fish kills have been documented.

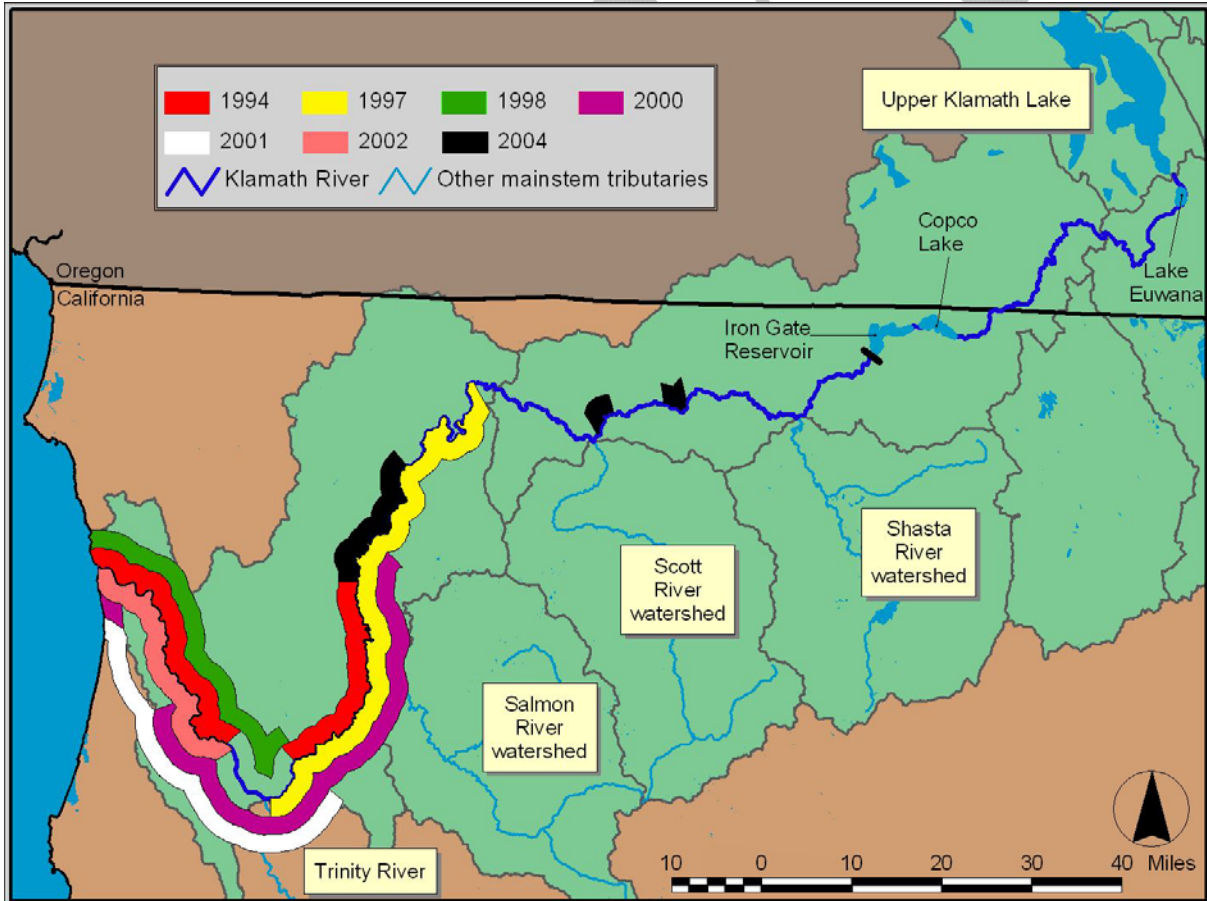


Figure 2.25: Fish Kill Years and Locations in the Klamath River in California

It is believed that juvenile fish kills are very common in the Klamath River from Iron Gate Dam to the mouth of the river but often go undetected. Direct observation of juvenile fish kills is not common due to the small size of the juvenile fish within the large

PRELIMINARY REVIEW DRAFT

river system and the generally small number of outmigrant traps that operate in the river (Klamath Fish Health Assessment Team [KFHAT] 2005, p.5, 6).

Juvenile fish kills in the Klamath River in California have been documented for the years 1994, 1997, 1998, 2000, 2001, and 2004 (Table 2.13). Estimates of the number of dead fish range from 269-300,000 juvenile salmonids and non-salmonids. Disease was the ultimate cause of death in all juvenile fish kills documented. The effects of disease were exacerbated by poor water quality conditions, including low DO, high water temperature, high ammonia concentrations, and low flow. Temperatures documented during these fish kills were as high as 25 °C, well above the lethal threshold for juvenile salmonids. Additionally, DO levels as low as 3.1 mg/L were recorded during these fish kills, which is well below the current Basin Plan objective of 8 mg/L.

Table 2.13: Juvenile Fish Kill Locations and Causes in the Klamath River in California

Year	River Location	Fish	Cause of Death	Exacerbating Factors				Citations
				D.O.	Temp	NH ₃	Flow	
1994	middle/ lower	~300 Chinook	Non stated		X			Foott (2005) USFWS (1997)
1997	middle	non-salmonids salmonids	Disease	X	X	X	X	Hannum (1997) Hendrickson (1997) USFWS (1997)
1998	various	~148,000 Chinook	Disease	X	X		X	Williamson and Foott (1998)
2000	middle/ lower	10,000-300,000 Chinook & steelhead	Disease	X	X			CDFG (2000, p.1, 10, 11), Deas (2000), Foott (2000), USFWS (2003a)
2001		269 Chinook ¹	Disease					Foott et al. (2002)
2004	upper/ middle	<250,000 Chinook	Disease		X			Engbring (2004) KFHAT (2005) Klamt and Carter (2004)

¹ It is likely that the peak of the disease epizootic and associated mortalities of juvenile Chinook likely occurred prior to when KFHAT conducted their reconnaissance surveys, and thus the actual number of dead fish was much higher (KFHAT 2005).

Documentation of adult fish kills in the Klamath River in California is available for 1997 and 2002 (Table 2.14). The 1997 fish kill was determined to be caused by Columnaris and other diseases and was exacerbated by maximum water temperatures around 26°C, low DO levels of 3.1 mg/L, low flows, and high ammonia concentrations (Hannum 1997; Hendrickson 1997).

In mid to late September 2002 at least 34,000 fish died in the lower 36 miles of the Klamath River, although actual losses may have been more than double this number (CDFG 2004, p.III). Approximately 98.4% (33,527) of the fish killed were anadromous salmonids, representing 19.2% of the total 169,297 Klamath-Trinity run for 2002 (USFWS 2003b p.ii).

PRELIMINARY REVIEW DRAFT

Table 2.14: Adult Fish Kill Locations and Causes in the Klamath River in California

Year	River Location	Fish	Cause of Death	Exacerbating Factors					Citations
				D.O.	Temp	NH ₃	Flow	Sediment	
1997	middle	>50/day non-salmonids	Disease	X	X	X	X		Hannum (1997) Hendrickson (1997) USFWS (1997)
2002	lower	>34,000 (including >33,500 salmonids)	Disease		X		X	X	USFWS (2003a) USFWS (2003b) CDFG (2004)

Multiple compounding factors likely contributed to the 2002 fish kill, including an early large run of fall Chinook, low river discharge which did not provide suitable attraction flows to trigger upstream migration, and warm water temperatures which were optimal for disease proliferation (CDFG 2004, p.III, 33, 124; USFWS 2003a, p.ii). Additionally, fish passage through the lower Klamath River may have been impeded by the shallow depth of the water flowing over some riffles, which were created by sediment deposition during high discharge events in the winters of 1997 and 1998 (CDFG 2004, p.III; USFWS 2003a, p.37). The majority of the dead fish examined were infected with the fish diseases *Ichthyophthiriasis* (Ich) and Columnaris, which was identified as the principal cause of death (CDFG 2004, p.III; USFWS 2003a, p.ii). Maximum daily water temperatures recorded at Turwar (RM 7) during September ranged from 18-23°C (CDFG 2004, p.70). Seven-day running averages of the weekly maximum temperature (MWMT) during this period ranged from 19-22.5°C (CDFG 2004, p.70), which exceeds the USEPA (2003) MWMT threshold values of 16°C (adult migration/core juvenile rearing), 18°C (adult migration/non-core juvenile rearing), and 20°C (adult migration). Although these high water temperatures are not unusual for the Klamath River, they are ideal for disease proliferation and thus contributed to a disease epizootic (the equivalent of an epidemic in humans) (CDFG 2004, p.III, 124; USFWS 2003a, p.ii).

2.5.1.3 Adult and Juvenile Salmonid Migration Barriers and Spawning and Rearing Habitat Degradation

Unless otherwise specified, the following information is from CDFG 2004 (p.III, 83), Hardy and Addley 2006 (p.10, 15, 20), and USFWS 2003a (p.ii, 36).

Poor water quality conditions are contributing to the impairment of migration (MIGR) of aquatic organisms, particularly salmonids. Section 2.3.4.1 summarized findings by Strange (2007) that adult fall Chinook salmon migration is dependent on stream temperature. As shown in Section 2.4.2 Klamath River mainstem and tributary water temperatures during the period of fall Chinook migration are often over the temperatures noted by Strange (2007) that inhibit upstream migration. Thus elevated water temperatures contribute to the impairment of MIGR.

Alterations in flow in the Klamath River basin have contributed to the degradation of salmonid spawning and rearing habitat (SPWN). Principal factors affecting anadromous fish production in the Klamath River from Iron Gate Dam to Weitchpec include impaired flow in some tributaries (particularly the Shasta and Scott Rivers), impaired flows in the

PRELIMINARY REVIEW DRAFT

mainstem, and alterations to the timing and magnitude of mainstem flows. Alterations in flow due to the presence of dams have resulted in armoring of the streambed, which combined with a lack of gravel recruitment from upstream sources, has resulted in degraded spawning habitat (Hardy and Addley 2006, p.15). One of the primary limiting factors for anadromous fish production in the Klamath River from Weitchpec to the mouth is the cumulative effect of impaired flow and alterations in the seasonal hydrograph. These impacts have contributed to the degradation of available spawning gravel from sedimentation (Hardy and Addley 2006, p.20).

Cumulative impacts resulting in sediment delivery to many tributaries of the Klamath River in California, in conjunction with alterations in the hydrograph of the mainstem, which has reduced high flows that historically flushed sediment through the system, have contributed to the formation and persistence of large delta fans at many tributary confluences, impeding adult and juvenile migration (MIGR). In low flow years, this accumulation of sediment can inhibit or block access to these tributaries, thereby restricting access to habitat and thermal refugia for migrating adult and juvenile salmonids. Salmonids that are unable to enter the tributaries are forced to seek space in the limited areas of thermal refugia in the mainstem Klamath River. Overcrowding of salmonids in mainstem thermal refugia areas, combined with the high water temperatures can exacerbate disease proliferation.

As mentioned in the previous section, there is evidence that conditions inhibiting adult migration may have contributed to the 2002 adult fish kill in the Klamath River. USFWS reported that in 2002 Klamath River flows were too low to trigger upstream migration causing adults to congregate in the lower river. After the fish kill was underway the U.S. Bureau of Reclamation increased flows, and salmonids responded by migrating out of the lower river. CDFG hypothesized that fish passage may have been impeded by shallow water depth over certain riffles, resulting from low flows and lack of cues for upstream migration.

CDFG...reported that in 1997 and 1998 high discharge events occurred in northern California that could have altered the channel of the Klamath River. They suggested that the input of high sediment loads during high discharge events could have resulted in the filling of pools and increased the elevation of riffles in the lower Klamath River. Furthermore, they speculated that discharges that may have been sufficient for fish passage in low discharge years prior to 1997 were inadequate for passage in September 2002 (CDFG 2003b, as cited by USFWS 2003a, p.37).

Additionally,

USFWS biologists working on the lower Klamath River [in September of 2002] observed low-flow conditions, making it more difficult to traverse shallow riffles in a jet boat than in previous years (Shaw 2002, personal communication). They observed that water depth at Pecwan

PRELIMINARY REVIEW DRAFT

and Ah Pah riffles appeared shallow enough to be an impediment to adult fish passage. Yurok biologists also observed that fish passage over some riffles was confined to multiple small channels, in which their jet boat with a six-inch draft, would occasionally touch bottom (Belchik 2003, personal communication). A former NMFS fisheries biologist (Gilroy 2003, personal communication) with experience working on the Klamath river suggested when flows are low, fish passage over certain riffles is confined to smaller channels, representing the main thalweg and much of the riffle is too shallow to pass fish. The DFG Fisheries Biologist, who has participated in angler surveys on the Klamath River since 1985, described water levels during September 2002 in the fish-kill area as the lowest she has observed in over 20 years of experience (Borok 2003, personal communication). These anecdotal observations raised concern that shallow water depth over certain riffles might have impaired the ability of salmon and steelhead to migrate upstream (CDFG 2004, p. 87).

Thus, alterations in flow and changes in channel conditions resulting from sedimentation in the mainstem Klamath River in California have contributed to the impairment of MIGR, and SPWN.

2.5.2 Impairment of Native American Culture (CUL) and Subsistence Fishing (FISH) Beneficial Uses

The Water Quality Control Plan for the North Coast Region (Basin Plan) includes two Native American Cultural beneficial uses; Native American Culture (CUL) and Subsistence Fishing (FISH). The CUL beneficial use covers “uses of water that support the cultural and/or traditional rights of indigenous people such as subsistence fishing and shellfish gathering, basket weaving and jewelry material collection, navigation to traditional ceremonial locations, and ceremonial uses”; FISH encompasses “uses of water that support subsistence fishing” (NCRWQCB 2007). CUL is designated as an “Existing” use in the Ukonom, Happy Camp, Seiad Valley, Klamath Glen, and Orleans Hydrologic Subareas of the Klamath River. Due to a lack of available information at the time of the last update of the Basin Plan, no waterbodies in the North Coast have been designated as “Existing” or “Potential” use for FISH. Based on the available information, however, California Regional Water Board staff consider FISH an existing use within the same Hydrologic Subareas of the Klamath River as those designated CUL.

The CUL beneficial use in the Klamath River in California is currently impaired due to the decline of salmonid populations and degraded water quality resulting in changes to or the elimination of ceremonies and ceremonial practices and risk of exposure to degraded water quality conditions during ceremonial bathing and traditional daily activities. The FISH beneficial use is currently impaired in the Klamath River basin in California due to the decline of salmonid populations and other Tribal Trust fish populations resulting in decreased use, abundance, and value of subsistence fishing locations, altered diet and associated physical and mental health issues, and increased poverty. Additionally, the presence of the toxin microcystin in fish and mussels in the Klamath River has the

PRELIMINARY REVIEW DRAFT

potential to impair both the CUL and FISH beneficial uses. It is important to note that other beneficial uses, such as COLD and MUN, are linked to the support of the CUL and FISH beneficial uses throughout the year.

2.5.2.1 Decline in Salmonid and Other Fish Populations

The decline of salmon populations, as well as the decline of other Tribal Trust fish species of the Klamath River basin in California including sturgeon, eulachon (candlefish), lamprey (eel) and some species of suckers, has impaired the CUL and FISH beneficial uses. The elimination of the spring Chinook run above the Salmon River has resulted in the elimination of cultural ceremonies associated with the migration of this species through the length of the Klamath River. Declines in fish populations, especially salmonids, has also resulted in decreased use, abundance, and value of subsistence fishing locations, an altered daily diet that has been linked to health issues for Tribal Members, and increased poverty.

An elaborate ceremony called the First Salmon Ceremony, marks the passing of the first spring Chinook salmon up the Klamath River. This migrating salmon was allowed to pass all the way up the Klamath River to its spawning ground. It was believed that the first spring Chinook migrating upstream would leave its scales at each spawning location for the rest of the salmon run to follow (Roberts 1932 as cited by Sloan 2003, p. 25). This first migrating salmon of the year was considered taboo, and if eaten would cause convulsions and death. Thus, the First Salmon Ceremony allowed this fish to pass safely upstream, thereby lifting the taboo, and allowing the Native People to fish for salmon in the river (Waterman and Kroeber 1938 as cited by Sloan 2003, p.25). The dramatic decline in the spring Chinook run has made it impossible for the Klamath River Tribes to conduct the First Salmon Ceremony. “And how do you perform the Spring Salmon Ceremony, how do you perform the First Salmon Ceremony, when the physical act of going out and harvesting that first fish won’t happen?”(Leaf Hillman 2004 as cited by Norgaard 2005, p.35).

The Karuk Tribe historically depended on the abundant populations of fish found in the mainstem Klamath River for subsistence. However, as fish populations have declined the Karuk have shifted their reliance to other food source (Reed 2007a). Ron Reed (2005), traditional dipnet fisherman and cultural biologist for the Karuk Tribe, states that there is only one remaining Tribal fishery location that provides any level of subsistence fishing to the Karuk Tribe, Ishi Pishi Falls. According to Reed (2005), in 2002, about 1,500 fish were caught at Ishi Pishi falls, in 2003 approximately 1,000 fish were caught, and in 2004 only 100 fish were harvested at this location. The limited harvest of fish at Ishi Pishi Falls has meant that even ceremonial salmon consumption is limited (Ron Reed Pers. Comm. as cited by Norgaard 2005, p.4). According to Norgaard (2006), in addition to declining salmonid numbers, the fishery at Ishi Pishi Falls is negatively affected by low flows. When flows are too low the ability to perform dip net fishing is limited and fewer fish are caught (Norgaard 2006).

The importance of fishing to Tribal Members is reflected by the fact that fishing locations are a form of real property (Pierce 2002, p.7-2; Sloan 2003, p.17). They can be owned by

PRELIMINARY REVIEW DRAFT

individuals, families, or a group of individuals, and can be borrowed, leased, inherited, and bought and sold (Sloan 2003, p.17, 18). The quality, use, and value of these fishing locations has been reduced as factors including increased siltation and decreased salmonid abundance have occurred in the Klamath River and its tributaries (Sloan 2003, p.18, 28).

Historically, the Karuk Tribe had a platform fishery associated with each of their 100 Tribal village sites (Reed 2006). These fisheries were located near the tops of riffles, where eddies were created along the margins of the Klamath River. These areas of low velocity were where the salmon would hold and/or utilize this microhabitat as a migration corridor. According to Reed (2006) these 100 platform fishery locations are no longer as productive as they once were, or are gone. Tribal elders convey that the riffles near these fishing areas have been filled in and flattened out by sediment, contributing to the decline in overall fish populations (Reed 2006), as well as contributing to the loss of a culturally significant way of life.

The decline of salmonids and other Tribal Trust fish populations in the Klamath River basin has altered the diet of each of the Tribes along the river and its tributaries. Historically, traditional consumption of fish by the Karuk Tribe was estimated at 450 pounds per person per year, while in 2003 the Karuk People consumed less than 5 pounds of salmon per person, and in 2004 less than ½ pound per person was consumed (Norgaard 2005, p.13). In 2005 over 80% of Karuk households surveyed reported that they were unable to harvest adequate amounts of lamprey (eel), salmon or sturgeon to fulfill their family needs (Norgaard 2005, p.4). Furthermore, 40% of Karuk households reported that there are fish species that their family historically caught, which are no longer harvested (Norgaard 2005, p.7).

The decrease in abundance and availability of traditional foods, including salmon, trout, eel, shellfish, sturgeon and riparian plants, is responsible for many diet related illnesses among Native Americans including diabetes, obesity, heart disease, tuberculosis, hypertension, kidney troubles and strokes (Joe and Young 1993 as cited by Norgaard 2005, p.9, 39). These conditions result from the lack of nutrient content in foods consumed in place of the traditional foods such as salmon, as well as from the decrease in exercise associated with fishing and gathering food (Norgaard 2005, p.40). The estimated diabetes rate for the Karuk Tribe is 21%, nearly four times the U.S. average, and the estimated rate of heart disease for the Karuk Tribe is 39.6%, three times the U.S. average (Norgaard 2005, p.40).

In addition to altered diet and increased health issues, declines in fish populations have resulted in a documented increase in poverty rates for some Klamath River Tribes.

The destruction of the Klamath river fishery has led to both poverty and hunger. Prior to contact with Europeans and the destruction of the fisheries, the Karuk, Hupa and Yurok tribes were the wealthiest people in what is now known as California. Today they are amongst the

PRELIMINARY REVIEW DRAFT

poorest. This dramatic reversal is directly linked to the destruction of the fisheries resource base.

The devastation of the resource base, especially the fisheries, is also directly linked to the disproportionate unemployment and low socio-economic status of Karuk people today. Before the impacts of dams, mining and over fishing the Karuk people subsisted off salmon year round for tens of thousands of years. Now poverty and hunger rates for the Karuk Tribe are amongst the highest in the State and Nation. The poverty rate of the Karuk Tribe is between 80 and 85% (Norgaard 2005 Exec Summary).

2.5.2.2 Degraded Water Quality

Degraded water quality in the Klamath River basin in California, including the seasonal presence of blue-green algae and algal toxins in the Klamath River and reservoirs (see Section 2.4.4), has impaired the CUL and FISH beneficial use. Known and/or perceived health risks associated with degraded water quality have resulted in the alteration of cultural ceremonies to exclude or limit ingestion of river water. Additionally, known or perceived risk of exposure to degraded water quality conditions during ceremonial bathing and traditional cultural activities such as bathing, gathering and preparing basket materials, and collecting and using plants has resulted in an impairment of CUL.

The presence of blue-green algae and algal toxins in the Klamath River and reservoirs has impaired the cultural practice of subsistence fishing. The Karuk Tribe has only one fishing location available to them and it is flow dependent. Thus, when fish are in the river and the flow is suitable for fishing, Tribal Members must fish even if blue-green algae and algal toxins are present in the river. Susan Corum, Water Resources Coordinator for the Karuk Tribe, states: "It is really not a choice to fish. It is part of their culture which they need to maintain (Corum 2007b)."

Microcystin has been identified in the waters of Klamath River, as well as in the liver of salmonids and in mussels from the river. Laboratory analyses detected a trace of microcystin in the liver of an adult steelhead, and 0.54 µg/kg in the liver of a half-pounder steelhead landed in the Klamath River at Weitchpec on October 3, 2005. Although these levels are not above the 250 ug/kg threshold which is advised by Van Buynder et al. (2001) to protect human health, the Yurok Tribe has expressed concern that the mid- to late summer blooms of *Microcystis* in the Klamath River generally coincides with increased salmonid upstream migrations and subsequent usage of salmonid meat for recreational, cultural, and sport purposes. Mussels in the Klamath River have also had detectable levels of microcystin found in them. In 2007, a mussel was found in the Klamath River containing >1500 ug/kg microcystin, over the threshold to protect human health advised by Van Buynder et al. (2001). The presence of microcystin in salmonids and mussels of the Klamath River has resulted in an impairment of the cultural practice of subsistence fishing.

The Klamath River Tribes practice their culture through their "World Renewal" ceremonial cycle, such as the "First Salmon Ceremony" and Jump Dance, the Boat

PRELIMINARY REVIEW DRAFT

Dance, the War Dance, and the White Deerskin Dance (Reed 2007b). Other Tribal ceremonies and rituals include the Brush Dance and the Flower Dance, as well as other rituals that require a spiritual cleansing process such as for fishing and hunting, funerals, and good luck (Reed 2007b). All of these ceremonies and rituals require Tribal members to be in close proximity to the Klamath River and they are integrally linked to the river and its health (Sloan 2003 p.18).

According to Karuk Cultural Biologist Ron Reed (2006, 2007b), the “World Renewal” ceremonial cycle is held on the Klamath River at Amerikirum (approximately 2 miles below Somes Bar), Clear Creek (Inam), Somes Bar (Katimin), and Orleans (Panamnik) starting in April and continuing through September of each year. The Medicine Man, who leads the ceremony at Clear Creek, walks 14 miles through the ridges and hills along the Klamath River and is joined halfway through his journey by children and adults of the Tribe who follow him the rest of the way for good luck. Upon reaching the Klamath River at the end of this walk, it was historically tradition to drink water from the river to complete the ceremony. This is no longer done due to health concerns about drinking water directly from the river, though children are still known to jump in and drink the water (Reed 2006).

Ceremonial bathing in the river is an important part of most ceremonies (Curtis 1924 as cited by Sloan 2003, p.28). For example, bathing in the Klamath River and its tributaries is a requirement for participants in the Brush Ceremony (Sloan 2003, P.16). “During the Fish Dam Ceremonies at *Kepel*, young girls were selected by the Medicine Man to participate in the ceremonies. Once selected, they were sent to the river to bathe and then were dressed in full regalia which they would wear during the ceremonies. Then they were sent home to their families, and were required to fast and bathe in the river every day” (Van Stranlen 1942 as cited by Sloan 2003, p. 28). During the World Renewal Ceremonies, the Medicine Man and other participants bathe in the Klamath River for up to 10 days (Reed 2006).

Bathing is also associated with funeral services, subsistence practices, recreational swimming, courtship, and for individual hygiene (Reed 2007a). Bathing associated with funeral rituals occurs year round and includes preparation for burial, and purification after burial (Curtis 1924 as cited by Sloan 2003, p.28). The Karuk Tribe historically bathed freely in the Klamath River, however in more recent years degraded water quality conditions during the summer have forced them to take precautionary steps while bathing in the river (Reed 2007a). The Yurok Tribe has reported that detached algae have been present in the Klamath River in amounts high enough to prevent access and negatively affect the spirituality associated with bathing areas (McKernan 2006).

Willow roots, wild grape, Cottonwood, and Oregon Grape are collected by Tribal Members in the riparian zone of the Klamath River and used to make baskets (Reed 2007a). Traditional collection of these basketry materials often involved wading in the water (Sloan 2007a), and further contact occurs when the material is washed and cleaned in the water (Reed 2007a). Additionally, willow roots are peeled by mouth following cleaning with river water (Reed 2006). In addition, plants are collected for food,

PRELIMINARY REVIEW DRAFT

medicine, materials, and other cultural functions (Reed 2007a). Gathering plants or plant materials involves wading and contact with the Klamath River (Sloan 2007a; Reed 2007a). Ingestion of water can occur because plants are often cleaned in the river water and water is consumed with medicinal plants (Sloan 2007a). Given degraded water quality conditions, ingestion of water may pose a potential health risk.

Table 2.15 provides a summary of the activities that are encompassed by the CUL and FISH beneficial uses. Table 2.15 also denotes when those activities occur during the year, and the footnotes identify the amount of physical contact with the water associated with each of these activities. This table is not comprehensive, but conveys the magnitude and diversity of activities that are covered under these uses. Based on the information presented, California Regional Water Board staff find that the CUL and FISH beneficial uses of the Klamath River in California are not being fully supported.

2.5.3 Impairment of Water Contact Recreation (REC-1), Non-Contact Water Recreation (REC-2), and Municipal and Domestic Supply (MUN)

Toxigenic cyanobacteria (blue-green algae) blooms and their associated toxins measured in Copco and Iron Gate Reservoirs and in select reaches of the Klamath River downstream from the reservoirs are periodically impairing the Water Contact Recreation (REC-1) and Non-Contact Water Recreation (REC-2) beneficial uses. Additionally, the toxins have the potential to impair Municipal and Domestic Supply (MUN) beneficial use in the Klamath River.

2.5.3.1 Recreational Impacts

The available data on blue-green algae and toxin concentrations in the Klamath River and reservoirs are presented in Section 2.4.4.2. Water contact recreation (REC-1) during swimming, diving, and other direct water contact presents a high risk of exposure to inhalation or ingestion of cyanotoxins in waters contaminated with *Microcystis aeruginosa* (or other toxigenic species). Blooms of *Microcystis* and the presence of its cyanotoxin, microcystin, have prompted health advisories in local newspapers as well as the posting of on-site warnings for the public to use caution during water contact recreational activities in Iron Gate and Copco Reservoirs and some reaches of the river since 2005.

The presence of elevated *Microcystis* and microcystin concentrations Iron Gate and Copco Reservoirs during August 2005 prompted the California State Water Board cooperating with the California Regional Water Board, USEPA, and Karuk Tribe to issue a joint press release (CA SWRCB 2005). The press release warned of the potential adverse health effects to persons recreating in waterbodies of the Klamath River system contaminated with noticeably excessive algal concentrations. The Siskiyou County Health Department also issued a health advisory warning people about elevated toxin

PRELIMINARY REVIEW DRAFT

Table 2.15: Karuk, Yurok, and Quartz Valley Tribes Cultural Beneficial Uses (CUL and FISH) of the Klamath River and Tributaries⁴

RESOURCE	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CUL												
Plants ^{1,3}												
Fish ¹												
Fishing ^{1,2}												
Water-drinking, steaming, cooking ^{1,3}												
Rocks ¹												
Bathing ²												
Boating ^{1,2}												
Wildlife ¹												
Hunting & Trapping ¹												
River & Trail Access ¹												
Training ²												
Swimming ²												
Prayer & Meditation ¹												
Fish Dam ^{1,2}												
Washing ¹												
Meditation ¹												
Wood Gathering ¹												
Tanning Hides ¹												
Roots ^{1,3}												
Sticks, Shoots & Bark ¹												
Weaving ¹												
Shells ¹												
World Renewal Ceremonial Cycle ^{2,3}												
FISH												
Plants ^{1,3}												
Fishing ^{1,2}												
Eeling ^{1,2}												
Shellfish ^{1,2}												
Water-drinking, steaming, cooking ^{1,3}												
Rocks ¹												
Bathing ²												
Boating ^{1,2}												
Wildlife ¹												
River & Trail Access ¹												

Sources: Bowman 2006; Norgaard 2006; Reed 2007a, Reed 2007b; Sloan 2007a, Sloan 2007b

Indicates time of use.

1-Wading, 2-Full submersion, 3-Ingestion of water

4-Tributaries utilized by the Tribes of the Klamath River for cultural purposes include many of those from the Scott River down to the mouth of the Klamath river. Additionally, the Quartz Valley Tribe utilized all tributaries which flow into the Scott and Shasta Rivers. Tributaries considered as having cultural beneficial uses include any tributary that provides spawning or rearing, or provides a migration pathway for Tribal Trust species.

Note: This table is not an exhaustive list of all activities covered under the CUL and FISH beneficial uses.

PRELIMINARY REVIEW DRAFT

levels in Copco Reservoir. Additionally, warning signs were posted at key recreational access facilities around Iron Gate and Copco Reservoirs by the California Regional Water Board.

During mid-August 2006, large blooms of *Microcystis aeruginosa* and high concentrations of microcystin led the California State Water Board, Karuk Tribe, California Regional Water Board, and USEPA to issue another press release, again warning recreational water users and other area residents to use caution when near the reservoirs, or avoid water contact recreation altogether in locations with noticeable blue-green algal blooms in Copco and Iron Gate Reservoirs (CA SWRCB 2006). The Siskiyou County Health Department also issued a public health advisory for Iron Gate and Copco Reservoirs in 2005 (Siskiyou County Public Health Department 2006). In early September 2006 the California Regional Water Board posted warning signs at prominent recreational access points in both reservoirs reiterating the cautionary advisories contained in the earlier press release. In addition to these postings at the reservoirs, the Yurok Tribe posted health advisory signs along the mainstem Klamath River within the reservation borders (Fetcho 2006).

Microcystis scums were present in Iron Gate and Copco Reservoir from mid- to late-June 2007 at concentrations that prompted the California Regional Water Board to post precautionary health advisory signs at boat launches, campgrounds, swimming areas, and other high traffic, recreational use access points along the shorelines of the reservoirs. Shortly after the posting of the two reservoirs the USEPA as lead agency, with a number of state agencies, and the Yurok and Karuk Tribes issued a joint press release on July 5, 2007 advising the public to use caution when recreating at the two reservoirs (USEPA 2007). In August 2007, *Microcystis* cell counts in the mainstem Klamath River exceeded the California BGA Group's guidelines for posting health advisories. Consequently, California Regional Water Board staff posted precautionary health advisory signs at 24 locations along the mainstem Klamath River from the sport fishing access point at Iron Gate Hatchery to the Aikens Creek Campground.

2.5.3.2. Health Impacts

Blooms of *Microcystis aeruginosa*, and subsequent releases of its cyanotoxin, microcystin, during the summer and early fall in the mainstem Klamath River have the potential to impair the municipal and domestic supply (MUN) beneficial use. The California State Water Board's Department of Water Rights Information Management System (WRIMS 2006) shows numerous existing water rights that utilize in-river water withdrawals for sources of domestic drinking water and other uses. Nearly all of the water rights are located downstream from Iron Gate dam. The location, engineering, and timing of water withdrawals, as well as the magnitude and velocity of streamflow are factors that affect the possibility of entraining blue-green algae and their toxins in water supplies. There have been no documented human health impacts due to drinking or recreating in Klamath River water during *Microcystis* blooms. However, the presence of the toxin during periods when water withdrawals are occurring and when people are recreating, presents the possibility that human health impacts could occur.

In August of 2007, a dog became very ill a few hours after swimming in Copco Reservoir and drinking the water during a *Microcystis* bloom (Klamath Blue-Green Algae Workgroup 2007;

PRELIMINARY REVIEW DRAFT

Tobler 2007). The sick dog was taken to the vet and tests showed elevated levels of several enzyme indicative of liver disease. Microcystin is a liver toxin, and is capable of producing this type of an enzymatic response.

2.5.3.3. Aesthetic Impacts

Visible scums formed by the presence of *Microcystis aeruginosa* and other blue-green algae in Copco and Iron Gate Reservoirs present an aesthetic nuisance, potentially impacting the aesthetic enjoyment (REC-2) of these reservoirs. A study conducted by CH2M Hill for PacifiCorp, compiled interviews and survey responses of recreational water users about their experiences at locations along the Klamath River, including Copco and Iron Gate Reservoirs (PacifiCorp 2004). Interviewee's responses showed that water condition during the summer to early fall seasons has affected the quality and enjoyment of their experiences. The survey did not link responses to a specific time period; however, nearly all of the concerns expressed by respondents pertained to the summer and early fall recreational seasons of 2001 and 2002.

Approximately 70% (n = 89), of the responses to the interview questions stated water quality either detracted a lot or a little from their aesthetic enjoyment of the Klamath River within the geographical boundaries of the survey. By far, the most common complaint related to large amounts of "algae" and odors related to "algae." The survey data show that of the 70% of water uses reporting unfavorable recreational experiences with "algae," approximately 42% (n = 37) of those negative responses directly involved Iron Gate and Copco Reservoirs. Though not stated, presumably the "algae" in question were blue-green algal species that tend to accumulate along shorelines, forming scums and surface films during blooms.

2.5.4 ***Impairment of Commercial and Sport Fishing (COMM)***

The Commercial and Sport Fishing (COMM) beneficial use is currently impaired in the Klamath River in California, as demonstrated by restrictions and closures on the sport and commercial fishing industries in the basin and beyond. Salmonid population decline has resulted in severe reductions in available Chinook salmon for both the in-river and ocean troll commercial fishing communities, and sport fishing community. Additionally, federal regulations have eliminated the right to harvest coho salmon stocks due to their dwindling numbers. Evidence documenting declining numbers of salmonids returning to spawn in the Klamath River basin is discussed in detail in Appendix 2. The apparent disappearance of eulachon (*Thaleichthys pacificus*) spawning activity in the Klamath River (Belchik and Larson 1998) has resulted in the cessation of a historically important, commercially valuable non-salmonid fishery that was primarily utilized by Yurok Tribal members.

2.5.4.1 In-River Sport Fishing Impairment

Decreased salmon populations in the Klamath River have resulted in the alteration of fishing regulations further restricting the number of in-river fish harvested recreationally and the length of the recreational salmon in-river fishing season. For the 2006 season, the California Fish and Game Commission (Commission) decreased the number of days that recreational salmon fishing could occur by 11 days in the Klamath River below the Highway 96 bridge at Weitchpec (CFGF 2006). This was done in an attempt to ensure that the quota for in-river recreational harvest would not be met before Labor Day, allowing fishing during the holiday weekend (CFGF 2006).

PRELIMINARY REVIEW DRAFT

The documentation of microcystin toxin concentrations in fish tissue of yellow perch from Copco Reservoir above human health thresholds represents an impairment of in-river sport fishing. Table 2.16 presents data from 2005 and 2007 when salmonids were collected in the Klamath River and Yellow Perch were collected in the reservoirs to test for the presence of microcystin. As the table reflects, microcystin was detected in the liver of a salmonid collected at Iron Gate Hatchery at a level >250 ug/kg, which is over the threshold recommended by Van Buynder et al. (2001) to protect human health. Additionally, four of the yellow perch fish tissue samples and one of the liver samples collected in Copco Reservoir was >250 ug/kg. Yellow perch are commonly harvested from Copco and Iron Gate Reservoirs for consumption.

Table 2.16: Detection of Microcystin in Fish Tissue and Liver Samples from the Klamath River and Reservoirs

Location Fish Collected	Year	# of fish tissue samples where Microcystin Detected	# of fish tissue samples with Microcystin total >250 µg/kg	# of fish liver samples where Microcystin Detected	# of fish liver samples with Microcystin total >250 µg/kg
Klamath River	2005	0 of 2*	0	2 of 4*	0
Iron Gate Hatchery	2005	0 of 2*	0	0 of 2*	0
	2007	0 of 1*	0	1 of 1*	1
Iron Gate Reservoir	2007	15 of 19**	0	2 of 3*	0
Copco Reservoir	2007	18 of 19**	4	3 of 3*	1

*salmonid

** yellow perch

2.5.4.2 Ocean Sport Fishing Impairment

During the period from 1960 through 1965 there was no closed season for ocean salmon sport fishing north of Tomales Point (CDFG 1967). The catch limit during this period remained constant at 3 salmon per day. In 1960 and 1961 the minimum size limit for salmon was 22 inches, and in 1962 one fish of any size was allowed with the remainder to be over 22 inches. From 1963 through 1965 the minimum size limit was one salmon over 20 inches and two over 22 inches.

In contrast, the currently depressed state of the fall Chinook run in the Klamath Management Zone (KMZ), and the listing of coho as threatened on both the federal (1997 listing) and California (2005 listing) Endangered Species lists, has resulted in increased restrictions on the ocean sport fishery. The 2007 ocean sport fishing season in the Klamath Management Zone (KMZ), extending from Humbug Mountain, OR to Point Arena, CA, was open from May 5 to September 4th (PFMC 2007). However, the Klamath Control Zone, extending 6 miles north and south of the Klamath River and 12 miles off-shore, was closed in August. The catching of coho was prohibited and the Chinook catch was limited to two fish per day (PFMC 2007). Chinook were required to be a minimum of 24 inches in total length to be legal to keep (PFMC 2007). These greater restrictions have contributed to the impairment of the sport fishery in the Klamath River basin.

PRELIMINARY REVIEW DRAFT

2.5.4.3 In-River Commercial Fishery Impairment

Between 1912 and 1934 approximately 957,000 pounds of Chinook salmon, representing close to 55,000 fish, were harvested and preserved during a single fishing season in the Klamath River (Snyder 1931, p. 7, 8, 88, and 89). Daily salmonid catches by the Tribal commercial fishery commonly ranged from 7,000 to 10,000 fish per day, with a one-day high that was reportedly approximately 17,000 fish. Catch totals were mostly Chinook, but coho salmon, steelhead trout, lamprey, and green sturgeon were also caught and preserved (Snyder 1931, p. 7, 8, 88, and 89). Due to precipitous declines in salmonid populations attributed to over harvesting by the in-river commercial salmon fishery, the fishery was declared illegal and closed by court order in 1934. It was subsequently reopened by another court order in 1977; however, the Bureau of Indian Affairs closed the Tribal in-river commercial fishery the following year under a “conservation moratorium.” It remained closed until 1987, when it was again reopened (Pierce 1998; Yurok Perspectives 2001, p. 7.1-7.13).

In 1993 the Department of Interior modified catch limits for the Klamath River basin Tribes, allotting 50% of the available Klamath River basin salmon harvest to the Hoopa and Yurok Tribes, or an amount sufficient to support a moderate standard of living, which ever is less. Given the depressed condition of the Klamath River basin salmon stocks in 1993, the Department of Interior concluded that 50% of the salmon harvest during that year would be allocated to the Tribes because there weren’t enough fish to allow them to catch enough to support a moderate standard of living (50 CFR Part 661, NOAA 1993). Of the 50% allocated to the Tribes, 80% and 20% of that allocation, referred to as Tribal shares, are allotted to the Yurok and Hoopa Tribes, respectively. Currently, the Yurok and Hoopa Tribes are the only Tribes with Federally-recognized commercial fishing rights in the Klamath River (Pierce 1998; Yurok Perspectives 2001, p. 7.1-7.13)

From 1990 through 1998 the in-river Tribal fishery was closed to commercial gillnetting due to depressed salmon runs. In recent years, harvest rates for the Tribal gillnet fishery have varied and are currently so low that it is hard to support an in-river commercial fishery. For the 2006 salmon season the PFMC, working with the Klamath Fisheries Management Council, determined that the allowable Tribal share of the Klamath-Trinity River basin salmon harvest is 10,000 fish (PFMC 2006a). This would allocate 8,000 salmon to the Yurok Tribe and 2,000 salmon to the Hoopa Tribe from the in-river salmon fishery. The salmon allocated to the Yurok Tribe for 2006 are thought to be well below harvest levels capable of supporting a commercial fishery (Eureka Times-Standard 2006) and it is presumed the same also would be true for the Hoopa Tribe’s allocation.

2.5.4.4 Ocean Commercial Fishery Impairment

Salmon sold to fish buyers and processors within the Klamath Management Zone (KMZ) have dwindled significantly since 1976 through 1980 when an average of 143,900 Chinook and 72,100 coho salmon were delivered per season to the port of Crescent City alone (PFMC 2003, 2006b). From 1993 through the present, concerns about the plummeting coho salmon populations have led to the closure of the entire California ocean commercial troll for coho. In order to more rigorously protect all salmonid stocks within the KMZ, regulations on the ocean commercial fishery (consisting mostly of Chinook salmon) has been progressively more restrictive.

PRELIMINARY REVIEW DRAFT

The economic impacts to the fishermen and on-shore industries that support the ocean commercial salmon industry have been, and continue to be significant. The maximum dollar values for the ex-vessel price (the price received by fishermen for fish landed at the dock) adjusted to 2005 dollar values are presented in Table 2.17 for the four major ports in the KMZ. The seasons when regulatory closures prohibited commercial ocean salmon fishing are not shown in the table, and correspond to no income for fishermen.

Table 2.17: Estimates of Maximum Dollars for the ex-Vessel price of the Commercial Ocean Salmon Fishery for the Four Major Ports within the KMZ from 1976-1990 and 1991-2001.

Port	Year(s) ¹ / Maximum Dollars	Year(s) ¹ / Maximum Dollars
Brookings, OR	1976-1980 / 7,355,000	1991-1995 / 126,000
Crescent City, CA	1976-1980 / 5,931,000	1991-1995 / 9,000
Eureka, CA	1976-1980 / 8,884,650	1991 / 43,640
Fort Bragg, CA	1986-1990 / 14,902,000	2001 / 663,000

Source: PFMC 2006b

¹Multiple year's values represent the average income per year

As a result of the Klamath River fish kill in 2002, the 2006 ocean commercial troll non-Tribal salmon fishery was severely curtailed along much of the west coast by the PFMC. The potential offspring of the 2002 Chinook stocks, the four year age class, are that cohort of fish that were predicted to have subsequently returned to the Klamath River as spawners in 2006. In particular, within the KMZ, extending from Humbug Mountain north of Brookings, OR to Horse Mountain just south of Shelter Cove, CA, the 2006 season was closed (NOAA 2006). South of Horse Mountain to Point Arena the season was open only from September 1 through September 15, or when a Chinook salmon quota of 4,000 fish was reached. The extreme seasonal and take restrictions were deemed necessary by the PFMC to assure an adequate numbers of spawners returned to the Klamath River.

During 2007 the PFMC (2008) considered Chinook salmon stocks within the KMZ somewhat healthier than 2006 but only opened the ocean commercial Chinook season from September 10 - September 30, imposing a fleet quota of 6,000 fish. Chinook stocks south of the KMZ to Point Arena were deemed depressed to the point that the PFMC only allowed fishing during the periods from April 9-April 27 (fleet quota of 2,000 fish) and August 29-September 30 (no quota set). The ocean coho salmon fishery remained closed along the California coast for the entire fishing season.

2.6 Problem Statement Synthesis

Based on the analysis presented in this chapter, there is little doubt that the Klamath River is an impaired waterbody. The Klamath River TMDL problem statement has identified numerous water quality related factors that must be addressed in the TMDL allocations and the implementation plan. The following is a summary of the water quality conditions and impacts that are addressed in the TMDL.

- Nutrient concentrations in much of the Klamath River watershed are well above natural background levels and contribute to excess periphyton and phytoplankton growth, which

PRELIMINARY REVIEW DRAFT

in turn contributes to poor DO and pH conditions, and also contributes to increased abundance and exposure of fish to parasites (i.e., *Ceratomyxa shasta*).

- Conditions of low DO and high pH are persistent in much of the Klamath River and contribute to multiple impacts on cold water fisheries including: migration barriers, decreased growth and fecundity, decreased reproductive success, increased juvenile fish mortality, increased adult mortality, and lower overall fish populations.
- High levels of nutrients and the presence of impoundments have contributed to the development of nuisance levels of blue-green algae that have created potential health hazards for people exposed to reservoir and downstream river waters. This health hazard has negatively impacted both recreational and ceremonial use of the reservoirs and the river.
- Temperature conditions that exceed natural levels exist throughout the Klamath River basin and contribute to: chronic stress and sometimes acute lethal conditions for cold water fisheries, proliferation of fish diseases such as Columnaris, presence of migration barriers, lower reproductive success, increased juvenile and adult mortality, and lower overall fish populations.
- Excess sediment delivery to the Klamath River and tributary streams has contributed to habitat impairment, increased levels of nutrients, and contributed to the development of water column temperatures that exceed Basin Plan water quality objectives.
- Reduced flows have led to increased water column temperatures, the accumulation of organic matter, and low DO conditions which have contributed to impacts on aquatic life.
- Water quality objectives for temperature, DO, pH, biostimulatory substances, and toxicity are regularly exceeded in the Klamath River basin in California.

PRELIMINARY REVIEW DRAFT

CHAPTER 2 REFERENCES

- Anderson, C.W. and K.D. Carpenter. 1998. Water Quality and algal Conditions in the North Umpqua River Basin, Oregon, 1992-1995, and Implications for Resource Management. U.S. Department of the Interior, U.S. Geological Survey. Water Investigations Report 98-4125. Portland, OR. Pp. 78
- Armstrong, N.E., G.H. Ward. 2008. Correction, Finalization and Q/A Evaluation of Datasonde Data Sets and Display and Analysis of Datasonde Measurements. Prepared for Paul Zedonis U.S. Fish and Wildlife Service Arcata CA Fish and Wildlife Office. Dataset accessed February 2008.
- Bartholow, J.M. 1995. Review and Analysis of Klamath River Basin Water Temperatures as a Factor in the Decline of Anadromous Salmonids with Recommendations for Mitigation. Midcontinent Ecological Science Center, River Systems Management Section. Fort Collins, CO. May 11, 1995. 53pp.
- Bartholow, J.M., and S.G. Campbell, M. Flug. 2005. Predicting the Thermal Effects of Dam Removal on the Klamath River. Environmental Management, Vol. 34, No. 6, pp856-874.
- Bartholomew, J. and R. Stocking. 2006. Ceratomyxa Shasta and Parvicapsula Minibicornis: Preliminary Study Results. Oregon State University, Department of Microbiology. 5pp.
- Bartholomew, J. 2008. Personal communication with Dr. Bartholomew regarding a conceptual model image used during her presentation at the Klamath Fish Health Workshop in Fortuna, CA (March 2008) regarding factors contributing to increased incidence of salmon parasite infections. E-mails and telephone discussions permission granted for use of PowerPoint figure and text.
- Belchik, M.R., and A.S. Larson. 1998. A preliminary Status Review of Eulachon and Pacific Lamprey in the Klamath River Basin. Yurok Tribal Fisheries Program. Klamath, CA. April 1998. 24 pp.
- Beschta, R.L., Bilby, R.E., Brown, G.W., Holtby, L.B., and T.D. Hofstra. 1987, Stream temperature and aquatic habitat: fisheries and forestry interactions: in E.O. Salo and T.W. Cundy eds., Streamside management: Forestry and fishery interactions, Contrib. 57: University of Washington, College of Forest Resources, Seattle, p. 191–232.
- Bjornn, T. and D. Reiser. 1991. Habitat requirements of salmonids in streams. In Meehan, W. ed., Influences of Forest and Rangeland Management on Salmonids Fishes and Their Habitat. American Fisheries Society Special Publication 19. pp. 83-138.
- Bowman, C. 2006. Personal communication with Crystal Bowman, Quartz Valley Indian Reservation EPA Director via e-mail to David Leland (California Regional Water

PRELIMINARY REVIEW DRAFT

- Board Staff) on July 18, 2006. Attachment to e-mail regarding preliminary information from the Quartz Valley Tribe about cultural use of the Klamath River and its tributaries for use in the Klamath River Basin TMDL. 1pp.
- Brown, L.R. and P.B. Moyle. 1991. Status of Coho Salmon in California: Report to the National Marine Fisheries Service. Department of Wildlife and Fisheries Biology, University of California, Davis. 98pp.
- Brown, L.R., P.B. Moyle, and R.M. Yoshiyama. 1994. Historical Decline and Current Status of Coho Salmon in California. *North American Journal of Fisheries Management*. 14(2):237-261.
- Butcher, J. 2008a. Nutrient Dynamics in the Klamath River. Report to US EPA Region IX. San Francisco, CA. 26 pp.
- Butcher, J. 2008b. Nutrient Numeric Endpoint Analysis for the Klamath River, CA. Report to US EPA Region IX. San Francisco, CA. 40pp.
- California Blue Green Algae Work Group of the State Water Resources Control Board and Office of Environmental Health and Hazard Assessment (California BGA Group). 2008. Cyanobacteria in California Recreational Water Bodies: Providing Voluntary Guidance about Harmful Algae Blooms, Their Monitoring, and Public Notification. June 2008. 45pp.
- California Department of Fish and Game (CDFG). 1965. California Fish and Wildlife Plan. Volume III, Supporting Data. Part B-Inventory Salmon-Steelhead & Marine Resources. 356pp.
- California Department of Fish and Game (CDFG). 1967. Fish Bulletin 135. The California Marine Fish Catch for 1965 and California Salmon Landings 1952 through 1965. Marine Resources Branch.
- California Department of Fish and Game (CDFG). 2000. Report on "Documentation of the Klamath River Fish Kill, June 2000." October 25, 2000. Northern California-North Coast Region. 10pp. + attachment.
- California Department of Fish and Game (CDFG). 2002. Status Review of California Coho Salmon North of San Francisco. Report to the California Fish and Game Commission. The Resources Agency. Sacramento, CA. 232pp +appendices.
- California Department of Fish and Game (CDFG). 2004. September 2002 Klamath River Fish-Kill: Final Analysis of Contributing Factors and Impacts. Northern California-North Coast Region. 173pp.

PRELIMINARY REVIEW DRAFT

- California Department of Fish and Game (CDFG). 2006. Klamath River Basin Spring Chinook Salmon Spawner Escapement, River Harvest and Run-size Estimates. Megatable 1980-2006. 9pp.
- California Department of Fish and Game (CDFG). 2008. Klamath River Basin Fall Chinook Salmon Spawner Escapement, In-river Harvest and Run-size Estimates. Megatable 1978-2007. 10pp.
- California Fish and Game Commission (CFGC). 2006. Title 14. Fish and Game Commission Notice of Proposed Changes in Regulations. February 7, 2006. 5pp. Accessed December 19, 2007. Available at: <http://www.fgc.ca.gov/2006/7_50b91_1ntc1.pdf>.
- California State Water Resources Control Board (CA SWRCB). 2005. Federal, Tribal and State Authorities Advise Caution on Dangerous Klamath River Algae. CA SWRCB 05-019. September 30, 2005.
- California State Water Resources Control Board (CA SWRCB). 2006. More Blue-Green Algae on Klamath River Than Last Year Say Local, Tribal, State and Federal Authorities. CA SWRCB 05-018. August 14, 2006.
- Corum, S. 2007a. Personal communication with Susan Corum, Water Resource Coordinator, Department of Natural Resources, for the Karuk Tribe via telephone conversation with Elmer Dudik (California Regional Water Board staff) on June 6, 2007.
- Corum, S. 2007b. Personal communication with Susan Corum, Water Resource Coordinator, Department of Natural Resources, for the Karuk Tribe via e-mail to Katharine Carter (California Regional Water Board staff) on December 18, 2007.
- Coutant, C.C. 1987. Poor Reproductive Success of Stripped Bass from a Reservoir with Reduced Summer Habitat. Transactions of the American Fisheries Society. 116:154-160.
- De la Fuente, Juan and Don Elder. 1998. The flood of 1997, Klamath National Forest, Phase I Final Report. November 24, 1998. Klamath National Forest. Yreka, CA. 76 p. plus appendices.
- Deas, M. 2000. Brief Synopsis of Available Hydrologic, Meteorologic, and Water Temperature Data, June 15-July 7, 2000. July 14, 2000. 7pp.
- Eilers, J., J. Kann, J. Cornett, K. Moser, A. St. Amand, C. Gubala. 2001. Recent Paleolimnology of Upper Klamath Lake, Oregon. Prepared by JC Headwater Inc., Roseburg, Oregon for U.S. Bureau of Reclamation, Klamath Falls, Oregon. March 16, 2001.
- Elder, D, B. Olson, A. Olson, and J. Villepontoux. 2002. Salmon River Sub-basin Restoration Strategy. Steps to Recovery and Conservation of Aquatic Resources.

PRELIMINARY REVIEW DRAFT

Report for The Klamath River Basin Fisheries Restoration Task Force, Interagency Agreement 14-16-0001-90532. USDA-Forest Service, Klamath National Forest. Yreka, Klamath National Forest and Salmon River Restoration Council. Sawyers Bar, CA. September 2002. 52 pp.

Engbring, J. 2004. Klamath Fish Conference Call, June 17, 004. Notes. 2pp.

Eureka Times-Standard. 2006. Klamath Confluence. John Driscoll, The Times-Standard. May 22, 2006.

Fetcho, K. 2006. Klamath River Blue-Green Algae Bloom Report, Water Year 2005. Yurok Tribe Environmental Program. January 2006.

Fetcho, K. 2007a. Klamath River Blue-Green Algae Bloom Report. 2006. Yurok Tribe Environmental Program, March 2007.

Fetcho, K. 2007b. Memorandum to the Klamath River BGA Workgroup. Yurok Tribe Environmental Program, September 26, 2007.

Foott, J.S. 2000. Klamath River Fish Kill Update. Memorandum. July 18, 2000. United States Fish and Wildlife Service. California-Nevada Fish Health Center. Anderson, CA. 2pp.

Foott, J.S., T. Martinez, R. Harmon, K. True, B. McCasland, C. Glace, and R. Engle. 2002. FY2001 Investigational Report: Juvenile Chinook Health Monitoring in the Trinity River, Klamath River, and Estuary. June-August 2001. U.S. Fish and Wildlife Service, California-Nevada Fish Health Center. Anderson, CA. 32pp.

Foott, J.S. 2005. Fish Health Issues in the Lower Klamath River Basin. Presentation given at the 2005 Klamath River Fish Health Workshop. November 2005. U.S. Fish and Wildlife Service, California-Nevada Fish Health Center.

Foott, J.S. 2006. Excerpt of a personal communication with Scott Foott of the United States Fish and Wildlife Service, California/Nevada Fish Health Center via e-mail to Katharine Carter (California Regional Water Board Staff) on October 13, 2006.

Hallock, R.J., R.F. Elwell, and D.H. Fry, Jr. 1970. Migrations of adult king salmon *Oncorhynchus tshawytsca* in the San Joaquin Delta as demonstrated by the use of sonic tags. California Department of Fish and Game, Fish Bulletin 151. 92pp.

Hampton, M. 2004. Shasta River Fish Counting Facility, Chinook and Coho Salmon Observations in 2003, Siskiyou County, CA. California Department of Fish and Game. Yreka, CA. 19 pp.

PRELIMINARY REVIEW DRAFT

- Hampton, M. 2005a. Shasta River Fish Counting Facility, Chinook and Coho Salmon Observations in 2004, Siskiyou County, CA. California Department of Fish and Game. Yreka, CA. 19 pp.
- Hampton, M. 2005b. Chinook and coho salmon update for Shasta River and Bogus Creek. E-mail and attachments from Mark Hampton of the California Department of Fish and Game on December 9, 2005, 12:29PM. Forwarded to Matt St. John of California Regional Water Board Staff by David Webb January 9, 2006, 2:41PM.
- Hannum, J.R. 1997. Fish Mortality in Klamath River August 4-14, 1997. Interoffice Memorandum. April 15, 1997. North Coast Regional Water Quality Control Board. Santa Rosa, CA. 3pp.
- Hardy, T.B. and R.C. Addley. 2006. Evaluation of Interim Instream Flow Needs in the Klamath River, Phase II, Final Report. Report prepared for USDI. Institute for Natural Systems Engineering. Utah Water Research Laboratory. Utah State University. Logan UT. July 31, 2006. 304pp.
- Hendrickson, G.L. 1997. Fish mortalities on Klamath River. Letter dated August 21, 1997. Humboldt State University, Department of Fisheries. Arcata, CA. 2pp.
- Herrmann, R.B., C.E. Warren, and P. Doudoroff. 1962. Influence of oxygen concentration on the growth of juvenile coho salmon. Transactions of the American Fisheries Society. 91:155-167.
- Hopelain, J.S. 1998. Age, Growth, and Life History of Klamath River Basin Steelhead Trout (*Oncorhynchus mykiss irideus*) as Determined from Scale Analysis. California Department of Fish and Game. Inland Fisheries Division Administrative Report No. 98-3. 23pp.
- Hoopa Valley Tribe Environmental Protection Agency (HVTEPA). 2008. Water Quality Control Plan Hoopa Valley Indian Reservation. Approved September 11, 2002, Amendments Approved February 14, 2008. Hoopa Tribal EPA. Hoopa, CA. 285 p.
- Independent Multidisciplinary Science Team (IMST). 2000. Influences of human activity on stream temperatures and existence of cold water fish in streams with elevated temperature. Report of a workshop. Technical report 2000-2 to the Oregon Plan for Salmon and Watersheds. Oregon Watershed Enhancement Board. Salem, Oregon. 35 p. plus appendices.
- Johnson, S. L. 2004. Factors influencing stream temperatures in small streams: substrate effects and a shading experiment. Canadian Journal of Fisheries and Aquatic Sciences. 61:913-923.

PRELIMINARY REVIEW DRAFT

- Jordahl and Benson, 1987. Effect of Low pH on Survival of Brook Trout Embryos and Yolk-Sac Larvae in West Virginia Streams. Transactions of the American Fisheries Society. 116:807-816.
- Kann, J. 2005. Technical Memorandum: Toxic Cyanobacteria in Copco and Iron Gate Reservoirs. Aquatic Ecosystem Sciences, LLC. Prepared for the Karuk Tribe of California. November 21, 2006.
- Kann, J. 2006. Technical Memorandum: *Microcystis aeruginosa* Occurrence in the Klamath River System of Southern Oregon and Northern California. Aquatic Ecosystem Sciences LLC. Prepared for the Yurok Tribe Environmental and Fisheries Programs. Klamath, CA. February 3, 2006.
- Kann, J. 2007. Technical Memorandum: Toxic Cyanobacteria Results for Copco/Iron Gate Reservoirs: October 29-30, 2007, Aquatic Ecosystem Sciences LLC. Ashland, Oregon. November 6, 2007.
- Kann, J. and E. Asarian. 2005. 2002 Nutrient and Hydrological Loading to Iron Gate and Copco Reservoirs, California. Kier Associates Final Technical Report to the Karuk Tribe Department of Natural Resources, Orleans, California. 5p pp +appendices.
- Kann, J. and S. Corum. 2006. Technical Memorandum: Summary of 2005 Toxic *Microcystis aeruginosa* Trends in Copco and Iron Gate Reservoirs on the Klamath River, CA. Aquatic Ecosystem Sciences, LLC. Prepared for the Karuk Tribe Department of Natural Resources. Orleans, CA. March, 2006.
- Karuk Tribe of California. 2002. Water Quality Control Plan. Karuk Tribe Department of Natural Resources. Orleans, CA. 36 p.
- Kier Associates. 1999. Mid-term Evaluation of the Klamath River Basin Fisheries Restoration Program. Prepared for the Klamath River Basin Fisheries Task Force. April 1999.
- Klamath Blue-Green Algae Workgroup. 2007. Notes from All Group Conference Call on Sept. 25, 2007.
- Klamath Fish Health Assessment Team (KFHAT). 2005. End of Year Report, 2004. March 16, 2005. Available at: <<http://ncncr-isb.dfg.ca.gov/KFP/DesktopDefault.aspx>>.
- Klamath Resource Information System (KRIS). 2006. KRIS Klamath Chart Table Page, Shasta Racks data 1930-2002. Available at: <<http://www.krisweb.com/>>. Website accessed January 18, 2006.
- Klamath River Basin Fisheries Task Force (KRBFTF). 1991. Long Range Plan for The Klamath River Basin Conservation Area Fishery Restoration Program. Assistance from William M. Kier Associates. 403pp.

PRELIMINARY REVIEW DRAFT

- Klamath National Forest (KNF). 1999. Thompson/Seiad/Grider Watershed Analysis. Happy Camp Ranger District.
- Klamath National Forest (KNF). 2002. Horse Creek Ecosystem Analysis. Scott River Ranger District.
- Klamt, R. and K. Carter. 2004. June 21, 2004 Klamath River water quality snapshot-summary. North Coast Regional Water Quality Control Board. Santa Rosa, CA. 5pp.
- Ligon, F., A. Rich, G. Rynearson, D. Thornburgh, and W. Trush. 1999. Report of the Scientific Review Panel on California Forest Practice Rules and Salmonid Habitat: Prepared for the Resource Agency of California and the National Marine Fisheries Sacramento, Calif. 92pp. + appendices.
- Lisle, T.E. 1982. Effects of aggradation and degradation on riffle-pool morphology in natural gravel channels, northwestern California. *Water Resources Research*. 18(6): 1643-1651.
- MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring Guidelines to Evaluate Effects of forestry Activities on Streams in the Pacific Northwest and Alaska. EPA/910/9-91-001. Prepared for U.S. Environmental Protection Agency, Region 10 – Water Division. Seattle, WA. 166 pp.
- Marshall, L.E. 2005. Annual Report: Trinity River Salmon and Steelhead Hatchery, 2004-2005. Department of Fish and Game. Fisheries Programs Branch. Northern California, North Coast Region. 10pp.
- McKernan, K. 2006. Yurok Tribe Response to CUL beneficial uses request. Letter from Kevin McKernan, Director of the Yurok Tribe Environmental Program, to David Leland (California Regional Water Board Staff) on July 7, 2006.
- Moyle P.B., R.M. Yoshiyama, J.E. Williams, and E.D. Wikramanayake. 1995. Fish Species of Special Concern In California. Department of Wildlife and Fisheries Biology, U.C. Davis. Davis, CA. 272pp.
- Moyle, P.B. 2002. Inland Fishes of California, 2nd Ed. Berkeley and Los Angeles, CA. University of California Press.
- Murray and Ziebell. 1984. Acclimation of Rainbow Trout to High pH to Prevent Stocking Mortality in Summer. *The Progressive Fish-Culturist*. 46(3):176-179.
- National Oceanic and Atmospheric Administration (NOAA). 1993. Ocean Salmon Fisheries off the Coasts of Washington, Oregon, and California. 58 Federal Register 68063. December 23, 1993. Title 50, Volume 9, Chapter 6, Part 661.

PRELIMINARY REVIEW DRAFT

- National Oceanic Atmospheric Administration (NOAA). 2006. Southern OR/Northern CA Coasts Coho ESU Threatened. Northwest Regional Office, National Marine Fisheries Service, NOAA. Accessed July 13, 2006. Available at: <<http://www.nwr.noaa.gov/ESA-Salmon-Listings/Salmon-Populations/Coho/COSNC.cfm>>.
- National Research Council of the National Academies (NRC). 2004. Endangered and Threatened Fishes in the Klamath River Basin. Washington, D.C. National Academies Press.
- Nielsen, J.L., Lisle, T.E., and Ozaki, V. 1994. Thermally stratified pools and their use by steelhead in northern California streams. Transactions of the American Fisheries Society. 123:613-626.
- Norgaard, K.M. 2005. The Effects of Altered Diet on the Health of the Karuk People. Submitted to the Federal Energy Regulatory Commission Docket #P-2082 on Behalf of the Karuk Tribe of California. November 2005.
- Norgaard, K.M. 2006. Personal communication with Dr. Kari Marie Norgaard, Assistant Professor of Sociology and Environmental Studies at Whitman College via e-mail to David Leland (California Regional Water Board Staff) on July 7, 2006. Attachment to e-mail regarding preliminary information from the Karuk Tribe about CUL and FISH beneficial use impairment for use in the Klamath River Basin TMDL. 7pp.
- North Coast Regional Water Quality Control Board (NCRWQCB). 2006. Staff Report for the Action Plan for the Shasta River Watershed Temperature and Dissolved Oxygen Total Maximum Daily Loads. May 3, 2006. 259pp.+appendices.
- North Coast Regional Water Quality Control Board (NCRWQCB). 2007. Water Quality Control Plan for the North Coast Region (Basin Plan). January 2007.
- Oregon Department of Environmental Quality (ODEQ). 1995. Dissolved Oxygen: 1992-1994 Water quality standards review. Final Issue Paper. 166pp. Available at: <<http://www.fishlib.org/Bibliographies/waterquality.html>>. Website accessed August 20, 2004.
- Oregon Department of Human Services (Oregon DHS). 2005. Public Health Advisory Guidance for Toxic Cyanobacteria in Recreational Waters, DHS Environmental Program. Accessed May 20, 2007. Available at: <<http://www.oregon.gov/DHS/ph/envtox/docs/bgadecisioncriteria.dpf>>.
- Pacific Fisheries Management Council (PFMC). 2003. Review of 2002 Ocean Salmon Fisheries, Ch. IV; Appendices A, C, and D. February 2003. Accessed June 1, 2006. Available at: <<http://www.pcouncil.org/salmon/salsafe02/salsafe02.html>>.
- Pacific Fisheries Management Council (PFMC). 2006a. Preseason Report III, Analysis of Council Adopted Management Measure for 2006 Ocean Salmon Fisheries. Prepared

PRELIMINARY REVIEW DRAFT

- by the Salmon Technical Team. April, 2005. Accessed March 15, 2006. Available at: <http://www.pcouncil.org/salmon/salpre06.html> >.
- Pacific Fishery Management Council (PFMC). 2006b. Review of 2005 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, Oregon 97220-1384. Accessed March 15, 2006. Available at: <http://www.pcouncil.org/salmon/salsafe05/salsafe05.html> >.
- Pacific Fisheries Management Council (PFMC). 2007. Preseason Report III. Analysis of Council Adopted Management Measures for 2007 Ocean Salmon Fisheries. April 2007. Accessed December 18, 2007. Available at: <http://www.pcouncil.org/salmon/salpreIII07/salpreIII07.html> >.
- Pacific Fishery Management Council. 2008. Preseason Report III. Analysis of Council Adopted Management Measures for 2008 Ocean Salmon Fisheries. Portland, Oregon. April 16, 2008. Accessed June 11, 2008. Available at: <http://www.pcouncil.org/salmon/alpreIII07/salpreIII07.html> >.
- PacifiCorp. 2004. Application for New License for Major Project, Klamath Hydroelectric Project (FERC) Project No. 2082, Exhibit E. Portland, Oregon. February 2004.
- PacifiCorp. 2006. Attachment B – Causes and Effects of Nutrient Conditions in the Upper Klamath River. Klamath Hydroelectric Project, FERC No. 2082. Portland, OR. 58 pp.
- Poole, G. C., and C.H. Berman. 2001. An Ecological Perspective on In-Stream Temperature: Natural Heat Dynamics and Mechanisms of Human-Caused Thermal Degradation.
- Phinney, H. K., and C. Peek. 1960. Klamath Lake, an Instance of Natural Enrichment. Transactions of the Seminar on Algae and Metropolitan Wastes. April 27-29, 1960.
- Pierce, R.M. 1998. Klamath Salmon: Understanding Allocation. Klamath River Basin Fisheries Task Force, United States Fish and Wildlife Service, Cooperative Agreement #14-48-113333-98-GOZ. February 1998. 35 pp.
- Pierce, R.M. 2002. Dividing the Harvest. *IN: Proceedings of the 2001 Klamath Basin Fish and Water Management Symposium*. Klamath River Inter-Tribal Fish and Water Commission and Humboldt State University Colleges of Natural Resources and Sciences and Arts, Humanities, and Social Sciences. February, 2002.
- Reed, R. 2005. Impacts on the Tribe with Decline in the Fishery: Impacts on Way of Life. *IN: On Salmon and Tribes: The Deterioration of the Salmon Fishery and Health of a Northern California Tribe in the Klamath River Watershed*. University of California Davis. June 2, 2005.

PRELIMINARY REVIEW DRAFT

- Reed, R. 2006. Verbal Comments Received at the Klamath River TMDL CEQA Scoping Meeting. Cultural Biologist, Karuk Tribe of California. July 18, 2006.
- Reed, R. 2007a. Personal communication with Ron Reed, Cultural Biologist for the Karuk Tribe via e-mail to Beth Jines (State Water Resources Control Board Staff) on March 13, 2007. E-mail was forwarded by Beth Jines to Matt St. John (California Regional Water Board Staff).
- Reed, R. 2007b. Personal communication with Ron Reed, Cultural Biologist for the Karuk Tribe via e-mail to Matt St. John (California Regional Water Board Staff) on December 18, 2007.
- Resighini Rancheria Environmental Department. 2006. Draft Revisions of the Resighini Rancheria Tribal Water Quality Ordinance (Number 02-2006). Draft Revised Tribal Water Quality Ordinance of the Resighini Rancheria. Prepared by Kier Associates. Arcata, CA. Resighini Rancheria. Klamath, CA.
- Rushton, K.W. 2005. Annual Report: Iron Gate Hatchery, 2004-2005. Department of Fish and Game. Inland Fisheries. Northern California, North Coast Region. 19pp.
- Sinokrot, B.A., and Stefan, H.G. 1993. Stream temperature dynamics: Measurements and modeling. Water Resources Research. 29(7)2299-2312.
- Siskiyou County Public Health Department. 2006. News Release Number ALG 06-01. Accessed September 12, 2006. Available at: <http://www.Co.siskiyou.ca.us/phs>.
- Sloan, K. 2003. Ethnographic Riverscape: Klamath River Yurok Tribe Ethnographic Inventory (Draft). Prepared by the Yurok Tribe Culture Department for PacifiCorp. FERC Project No. 2082. November 2003.
- Sloan, K. 2007a. Personal communication with Kathleen Sloan, Tribal Archeologist and Assistant Director of the Yurok Cultural Resources Division, via e-mail to Katharine Carter (California Regional Water Board Staff) on September 19, 2007.
- Sloan, K. 2007b. Personal communication with Kathleen Sloan, Tribal Archeologist and Assistant Director of the Yurok Cultural Resources Division, via e-mail to Katharine Carter (California Regional Water Board Staff) on October 17, 2007.
- Snyder, J.O. 1931. Salmon of the Klamath River, California. Calif. Dept. of Fish and Game, Vol. 10, No. 4. 121 pp.
- Stocking R. W. and J. L. Bartholomew. 2004. Assessing links between water quality, river health, and Ceratomyxosis of salmonids in the Klamath River system. Oregon State University, Department of Microbiology. 5pp.

PRELIMINARY REVIEW DRAFT

- Strange, J. 2007. Adult Chinook Salmon Migration in the Klamath River Basin: 2005 Sonic Telemetry Study Final Report. Yurok Tribal Fisheries Program, and School of Aquatic and Fishery Sciences- University of Washington in collaboration with Hoopa Valley Tribal fisheries. January 2007. 96pp.
- Sutter, G.W. 1993. Ecological Risk Assessment. Boca Raton, FL. Lewis Publishers.
- Sutter, G.W. 1999. Developing conceptual models for complex ecological risk assessments. *Human and Ecological Risk Assessment*. 5(2): 375-396.
- Tetra Tech. 2006. Technical approach to Develop Nutrient Numeric Endpoints for California. Prepared for U.S. Environmental Protection Agency (Contract No. 68-C-02-108-TO-111), and CA State Water Resources Control Board – Planning and Standards Implementation Unit. Lafayette, CA. 120 pp.
- Tobler, H. 2007. Toxic lake warning in Calif. Ashland Daily Tidings, Letter to the Editor. Opinion and Editorial section. August 29, 2007.
- United States Environmental Protection Agency (USEPA). 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003. Office of Water Regulations and Standards Criteria and Standards Division. Washington, DC. 35pp.
- United States Environmental Protection Agency (USEPA). 1995. Watershed Protection: A Project Focus. EPA 841-R-95-003. Office of Water, U.S. Environmental Protection Agency, Washington, D.C.
- United States Environmental Protection Agency (USEPA). 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-98/002F. Risk Assessment Forum, USEPA, Washington, DC 94 pp.
- United States Environmental Protection Agency (USEPA). 1999a. Protocol for Developing Sediment TMDLs. EPA 841-B-99-004. Office of Water, U.S. Environmental Protection Agency, Washington, D.C.
- United States Environmental Protection Agency (USEPA). 1999b. Update of Ambient Water Quality Criteria for Ammonia. EPA 822-R-99-014. Office of Water, U.S. Environmental Protection agency, Washington, D.C.
- U.S. Environmental Protection Agency (USEPA). 2001. Issue Paper 5: Summary of technical literature examining the effects of temperature on salmonids. Region 10, Seattle, WA. EPA 910-D-01-005. 113pp. Available at: <http://yosemite.epa.gov/R10/water.nsf>>. Website accessed on July 2, 2004.
- United States Environmental Protection Agency (USEPA). 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Water Quality Standards. Region 10, Seattle,

PRELIMINARY REVIEW DRAFT

WA. EPA 910-B-03-002. 49pp. Accessed June 23, 2004. Available at:
<<http://www.epa.gov/r10earth/temperature.htm>>.

United States Environmental Protection Agency (USEPA). 2007. News Release: U.S. EPA, State, Tribes, warn against Klamath River blue-green algae: Contact with blue-green algae can cause eye irritation, skin rash. Released July 5, 2007.

United States Fish and Wildlife Service (USFWS). 1997. Letter dated September 23, 1997 to Bruce Gwynn (California Regional Water Board staff) from Bruce G. Halstead (USFWS staff) pertaining to TMDL on the Klamath River. Arcata, CA. 12pp.

United States Fish and Wildlife Service (USFWS). 2003a. Klamath River Fish Die-off, September 2002, Causative Factors of Mortality. Arcata Fish and Wildlife office. Arcata, CA. Report Number AFWO-F-02-03. 115pp.

United States Fish and Wildlife Service (USFWS). 2003b. Klamath River Fish Die-off, September 2002, Report on Estimate of Mortality. Arcata Fish and Wildlife office. Arcata, CA. Report Number AFWO- 01-03. 28pp.

United States Fish and Wildlife Service (USFWS). 2006. Comments on disease presence in the Klamath River in California by Scott Foott of the USFWS California/Nevada Fish Health Center during a panel discussion. Panel Discussion for the Klamath Basin Watershed Conference 2006: Sustainable Watersheds Bring Sustainable Communities. November 8, 2006.

Van Buynder, P.G., T. Oughtred, B. Kirkby, S. Phillips, G. Eaglesham, K. Thomas, and M. Burch. 2001. Nodularin Uptake by Seafood During a Cyanobacterial Bloom. *Environmental Toxicology*. 16(6): 468-471.

Vaux, W.G.. 1968. Intergravel flow and interchange of water in a streambed. Bureau of Commercial Fisheries Biological Laboratory. Auke Bay, Alaska. *Fishery Bulletin*. 66(3): 479-489.

Wagner, E.J., T. Bosakowski, and S. Intelmann. 1997. Combined Effects of Temperature and High pH on Mortality and the Stress Response of Rainbow Trout after Stocking. *Transactions of the American Fisheries Society*. 126:985-998.

Washington State Department of Ecology (WDOE). 2002. Evaluating Standards for Protecting Aquatic Life in Washington's Surface Water Quality Standards: Temperature Criteria. Draft Discussion Paper and Literature Summary. Publication Number 00-10-070. 189pp.

Water Right Information Management System (WRIMS). 2006. Water Rights Information for the Klamath River basin in California. State Water Resources Control Board, Division of Water Rights. Data downloaded October 3, 2006.

PRELIMINARY REVIEW DRAFT

- Welch, E.B. and J. M. Jacoby. 2004. Pollutant Effects in Freshwater: applied Limnology, Third edition. Spon Press. London, UK. 504 pp.
- Wetzel. 2001. Limnology: Lake and River Ecosystems. Third Edition. Academic Press. London, UK. 985 pp.
- Williamson, J.D. and J.S. Foott. 1998. FY98 Investigational Report: Diagnostic Evaluation of Moribund Juvenile Salmonids in the Trinity and Klamath Rivers (June-September 1998). United States Fish and Wildlife Service. California-Nevada Fish Health Center. Anderson, CA. 13pp + appendices.
- Wilzbach, P. 2008. Personal Communication (e-mail and telephone) regarding the effect of nutrient dynamics and algae rich waters from Iron Gate Reservoir on downstream polychaete and parasite populations. Klamath Fish Health Workshop 2008.
- Wondzell, S.M., and Swanson, F.J. 1999. Floods, channel change, and the hyporheic zone. Water Resources Research. 35(2): 555-567.
- World Health Organization (WHO). 1999. Toxic Cyanobacteria in Water: A Guide to Their Public Health Consequences, Monitoring and Management. London, England. 400 pp.
- World Health Organization (WHO). 2003. Guidelines for Safe Recreational Water Environments, Volume 1, Coastal and Fresh Waters. Geneva, Switzerland. 253 pp.
- Yurok Perspectives. 2001. Yurok Perspective of Trinity River Fisheries Resources. Accessed March 15, 2006. Available at: <www.humboldt.edu/~extended/klamath/proceedings2001/KLAMSYM7.PDF>.
- Yurok Tribe Environmental Program (YTEP). 2004. Water Quality Control Plan For the Yurok Indian Reservation. Yurok Tribe Environmental Program. Klamath, CA. 37 p.